MATERIALS & METHODS

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

FEBRUARY 1946

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Volume 23, Number 2 February, 1946

Cover Illustration

Aluminum alloy sheet is marked for proper identification in an automatic stencilling machine. (Courtesy: Reynolds Metals Co.)

NEXT ISSUE:

Diamond Dies for Wire Drawing
Low Temperature Treatment of Alloy Steels
Copper Brazing Steel Parts
Deep Drawing of Magnesium Alloys
High Temperature Metal Refining Furnace
Welding Stainless Steel
Radiography with Supervoltage X-Rays
Fabrication of Glass Reinforced Plastics

PRECISION INVESTMENT CASTINGS: "Materials & Methods Manual" No. 13

FUNDAMENTALS *and* APPLICATIONS OF INDUCTION HEATING

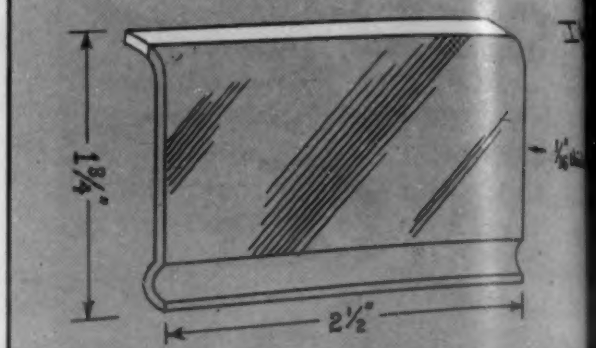
INDUCTION HEATING CORPORATION
NEW YORK CITY

Case Histories: Hardening & Brazing Applications

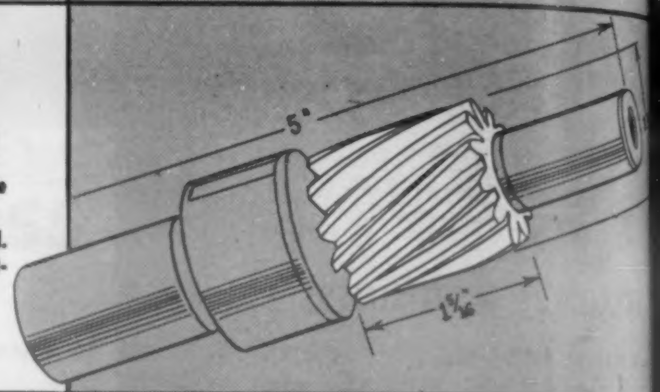
Data Sheet No.

ADVANTAGEOUS, NEW RENTAL-PURCHASE PLAN NOW MAKES "THERMONIC" INDUCTION HEATING EQUIPMENT READILY OBTAINABLE. INQUIRIES INVITED!

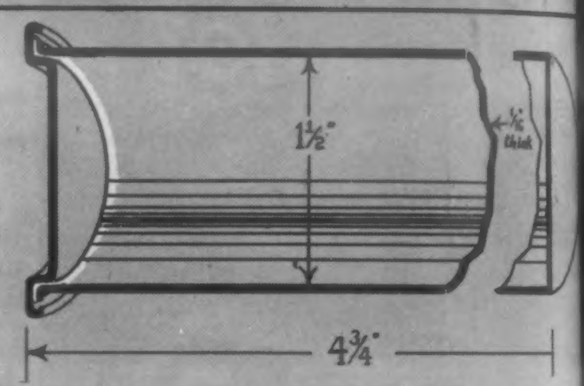
Job: To harden edge of Wood Scraper Blades.
Material: 90 to 100 carbon steel.
Production: 1 every 2½ seconds.
Equipment: 1 model #1070 Thermonic Induction Generator and a single position conveyor table.
Remarks: The blades were to 1450°F., 3/16" back from edge and water quenched. R.C. 64 to 67 was obtained.



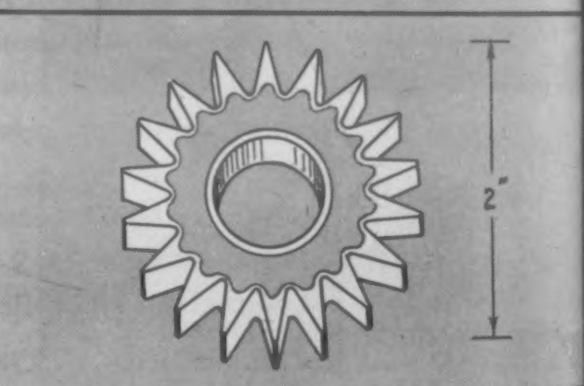
Job: To harden teeth of pinion.
Material: NE 8640.
Production: 1 every 8 seconds.
Equipment: 1 model #1070 Thermonic Induction Generator and single position table.
Remarks: The teeth were heated to 1500°F.-1600°F. and oil quenched. R.C. 53 to 57 was obtained. Part was rotated during the heating cycle.



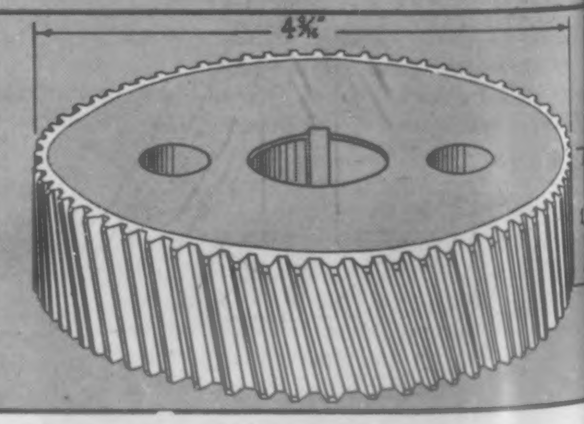
Job: To soft solder covers to round cans.
Material: Steel.
Production: 6 every 6 seconds.
Equipment: 1 model #1070 Thermonic Induction Generator and 2 position table.
Remarks: A ring of .072" 60/40 rosin core solder was preplaced at the joint. Alloy flowed through the sheer area.



Job: To harden the area around the center hole and the cutter teeth.
Material: Carpenter #11 special steel.
Production: Total time for both operations, 1 every 15 seconds.
Equipment: 1 model #1070 Thermonic Induction Generator and 2 position table.
Remarks: The teeth and inside hole of the cutter were heated to 1625°F.-1675°F. and water quenched. R.C. 63-65 on teeth and 52-55 in the area around the hole was obtained.



Job: To harden Helical Gear teeth.
Material: SAE X-1335.
Production: 1 every 13 seconds.
Equipment: 1 model #2200 Thermonic Induction Generator and single position table.
Remarks: The 73 teeth of the hellical gear were heated to 1500-1550°F., rotated and water spray quenched. R.C. 55 to 60 was obtained.



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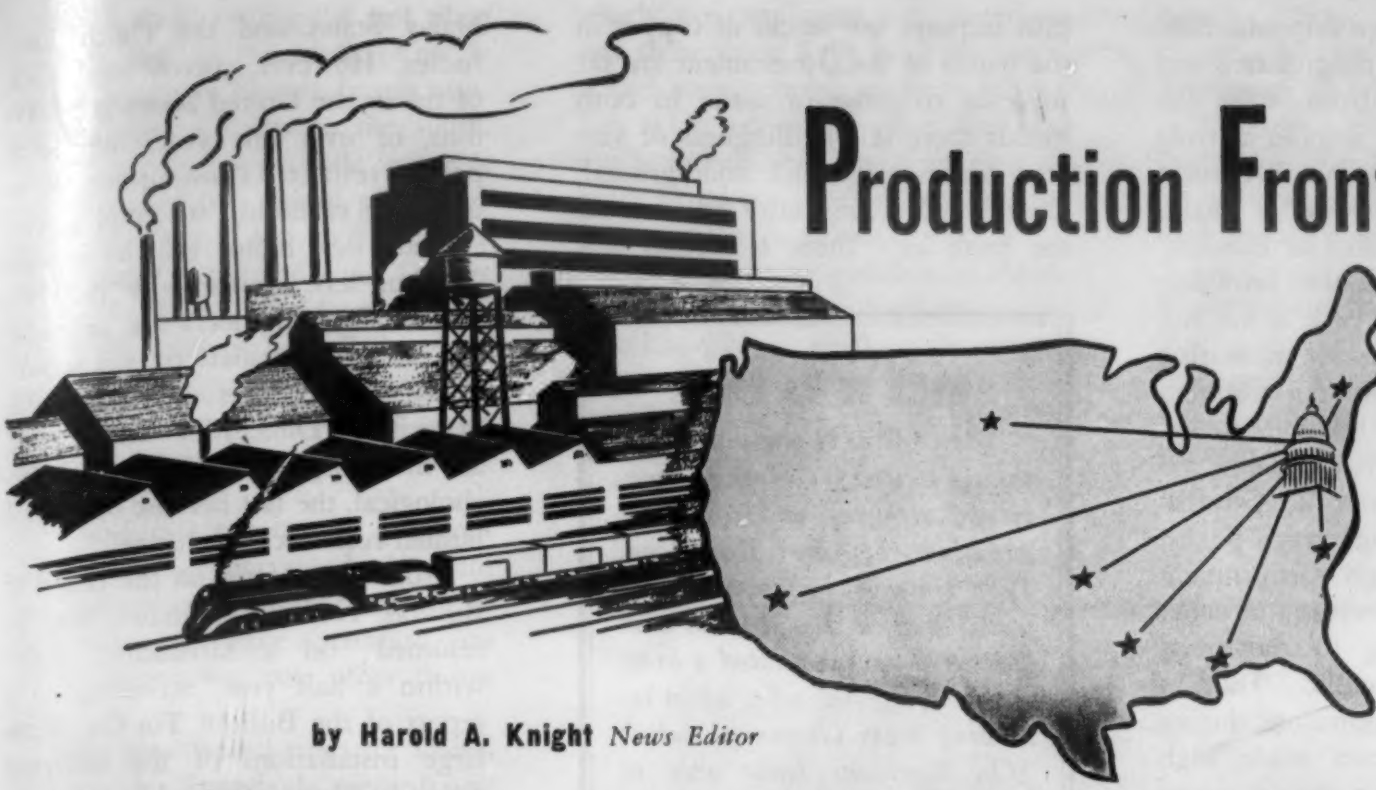


Production Frontiers

by Harold A. Knight *News Editor*

Up to our steel strike our economy was not bad. . . . Only 5% unemployed, or 2,000,000. . . . Take home pay not severely cut. . . . Our people have $28,000,-000,000 to spend. . . . Washington higher-ups are all out for high wages. . . . Our reaction to war rigors is natural. . . . But we need a President with a "big stick". . . . Washington labor expert predicts knock-down, drag-out fight between C.I.O. and A.F.L. . . . American people emotionally unready for reconversion.

Scarcities in lead, copper and tin. . . . Steel production lowest in tonnage since 1893; in percentage, lowest on record. . . . Billiton tin producers optimistic. . . . "Germans are a thoroughly beaten and frightened people. . . . Their industrial output 5 to 10% of normal". . . . "Boss" Kettering suggests being skeptical of "standards" . . . He tells of Diesel pistons that run for 1,500,000 miles. . . . He is unhappy when people are happy about mechanical performance.

In aircraft we were 10,000 changes behind. . . . How do you like our Boston boy cartoon? . . . When Germans destroyed blueprints, they had duplicates elsewhere. . . . Magnesium Christmas makes you light-hearted. . . . "Little man" meets three Presidents. . . . We take issue with another columnist.

Until the Steel Strike Our Economy Was Good

There is still considerable confusion as to whether the country is going to the damnation bow-wows or whether we are making progress on our reconversion. Let's look at the good factors first. The rapidity of reconversion and the tremendous volume of civilian goods being produced so soon after V-J Day has astounded many economic observers. The strikes, though spectacular, had caused an over-all reduction in production up to mid-January of only 5%.

Employment before the steel strikes was at the highest peace-time level in our history, with 52,000,000 workers holding productive civilian jobs. In many areas reconversion is 90% complete. Payrolls and individual earnings, which turned downward immediately after V-J day, are now only slightly below wartime peaks—and still rising, states the Committee for Economic Development.

The number of unemployed stands at only 2,000,000, judging from figures of the U. S. Census Bureau. Perhaps some of these are housewives who did not intend to be "gainfully" employed, come peace, anyway. Of course, there are still several million from our armed forces for whom jobs must still be found. Money in circulation is now $28,000,000,000, but there is a question whether this is a liability or an asset. If it were all "hot money"—watch out, inflation!

As to labor-management troubles and seeming 'unwillingness to work, most conservative economists and sociologists believe that, fortunately, this is only a passing phase. Remember that our nation has gone through one of the most serious ordeals in its history and has shed real sweat, blood and tears. It has passed through the ordeal with flying colors. Is it not logical that a loafing, care-free phase follow?

Remember, too, that during the war we threw to the four winds many hide-bound precepts of economy. The high school boy often received $80 per week. The cost of anything was hardly even a "mere detail." The Government itself yawned at mere millions and talked only in billions. Is it not natural, therefore, that the sense of values is a lost art?

Are We Emotionally Ready?

It may be, though, that a strong man is needed to whip us back to our senses, such as the heroic "Teddy" Roosevelt with his "big stick." Perhaps it is stated well by William P. Witherow, president, Blaw-Knox Co., who says: "Machines have reconverted, but men have not. We do not seem to be emotionally ready as a people. There is too much pressing for personal and group advantages. From the Pearl Harbor investigation to wage and price questions we are fighting yesterday's wars and arguments instead of tackling new jobs at hand. We are creating an artificial and needless crisis. We face the danger of an all-out fight between economic and occupational groups,

with resultant damage unpredictable. It is time for both progressives and conservatives to be liberal in the dictionary sense. That implies a truly free zone for enterprise. We must be concerned with creation of wealth —not its mere transfer or control."

We, ourselves, have been browsing around Washington with a kit full of mental gage blocks for measuring sentiment. We listened to a man high in Washington labor relations circles. Here is the gist of what he said:

"From top to bottom our Government stands for a high wage policy. The attitude of high Government men towards wage decreases at times will prove shocking to the more reasonably-minded public. Thus, a piano maker made munitions during the war and his men made high wages. Now he can't reduce wages to the normal piano-making level, according to the Government.

"Walter Reuther is not the leader of a union group, but the leader of a mob. They've whipped up a frenzy of hatred against employers. The stage is set for a tremendous war between the CIO and AFL, the antagonism in which is something frightful to behold. We are going to see more and more boycotts, jurisdictional disputes and sympathetic strikes. The CIO'S "one for all" policy begins to leak at the seams. The CIO will close ranks against craft unions. The present readjustment between labor and management just had to come—better to come early, as it has."

Lowest Steel Rate in History

History was made in the steel industry the week of Jan. 21 when operations were scheduled at only 4.9% of capacity, the lowest in percentage in the 300-year history of the industry. From a tonnage standpoint, scheduled production was the lowest in 53 years. Output of 89,700 tons for the week of Jan. 21 compares with the weekly average of 86,352 tons in 1893, an era when a large percentage of production was iron—not steel.

Supplies of metals have been coming in for serious consideration again. The shortage of lead is rather alarming, the scarcity being partly because of the American price of 6½c per lb. as against a world price of 7c, which tends to divert foreign lead away from the United States. In the case of copper, too, consumption is considerably greater than production plus imports, but stocks of copper in the hands of the Government are far superior to those of lead. In both metals there is unwillingness of veteran-miners to go back underground, having had a long taste of labor in the fresh air. There is serious talk of raising the price of lead from 6½ to 7c; of copper, from 12 to 14c.

Watch on the Rhine

World War II was due to our failure to watch Germany closely and act—say, at Hitler's occupation of the Rhineland. This time it behooves all to watch her closely. In our December issue we quoted a brass company official, who, upon returning from Germany, stated: "The Germans want only to work, work, work—and at a time when the rest of the world is trying its best to get out of work."

This is verified by Byron Price, former head, U. S. Office of Censorship, following an on-the-spot survey. He says:

"The Germans are a thoroughly beaten and frightened people. As a purely practical proposition, they know they will be required to pay heavily. They have gone back to work with a determination to live and to rebuild their country, whatever the cost; no people in Europe is working harder. Lacking transport, millions are walking unbelievable distances daily to obtain and hold jobs. Germany is plodding a weary road toward what destination it does not know.

"German industrial ouput in the American zone is 5 to 10% of normal, with increase extremely uncertain. There are severe shortages of materials, fuel, rolling stock and food. A prime problem is how to develop exports so Germany can pay."

Tin Supply is Still Tight

There is worry in the tin situation, especially since the bulk of the world's supply comes from the troubled areas of Burma, Siam, the Malay States and the Dutch East Indies. However, current total stock of tin in the United States is 95,000 tons, or over one year's supply at present restricted consumption. Wise users are curtailing tin employment.

Thus, new motor vehicles contain 2 lb. or less, against 4 lb. in 1940. Automotive engineers are redesigning parts to eliminate tin and are devising American-produced alternate materials. Difficulties encountered are metallurgical, economic and psychological, the last because of natural human resistance to change.

Production of tin on the island of Billiton, Netherland Indies, may be resumed "on a satisfactory scale" within a half year, according to a report of the Billiton Tin Co. Some large installations of the electrical works had been removed by the Japs, as well as cables and machines in repair shops. A number of dredges are available, but must be repaired. Two "super-dredges" were in fairly good condition. A stock of 310 tons of tin was intact. The Chinese workers on the island are "full of strength and willing to work." Perhaps this is typical throughout the Far Eastern tin areas.

Philosophy of "Boss" Kettering

Why read about musty old characters in fiction, such as those portrayed by Charles Dickens, when we have a real character with us in the United States today—a character of real homespun qualities, salty in his utterances, and with down-to-earth philosophy in his sayings? We refer to C. F. ("Boss") Kettering. We read with many a chuckle an article by him in a recent copy of "Reader's Digest." More recently he talked before the Detroit meeting of the American Society for Testing Materials. We present snatches of this talk:

"Sometimes standardization and methods of testing become static. We've had a very interesting experience in trying to standardize tests on paints and varnishes. The Florida people said no one ought to kick about an automobile finish failing down there because you got something back for it—plenty of sunshine. Designing new instrumentation we found that paints failed just exactly opposite from what everybody thought they did! The hotter the sunlight, the less they failed.

"By standard testing the test plate faced 45 deg. to the south. That is okay in winter in Florida, but in summer shadows are cast to the south. They forgot to put latitude into this test. We used two sets of plates, exposing one from 6 a.m. to 6 p.m.; the other from 6 p.m. to 6 a.m. The set exposed at night failed four times as fast as the daytime one. Failure was just plain ordinary dew. We rigged up dewmeters and found that plates failed in proportion to the number of hours of dew.

"I think that continually questioning whether or not standards could be improved is very important. Sometimes when you make a standard, you set up things that rule other things out.

"Take pistons and rings for Diesel locomotives. Everybody seemed perfectly happy to change them at 60 or 70,000 miles. I was unhappy that they were happy. When I questioned them, a typical answer would be: 'Well, if you were dragged 60,000 miles over a surface, maybe you would want to be changed, too! We found that where the top piston stopped it always eroded and the cylinders would wear a little groove where the top ring stopped. I can show you a stack of papers 4 ft. high on all the theories of the world as to why that is.'

"We found the reason it eroded was because it got too hot. No one had ever measured the temperature. So we developed an entirely new type of piston and ring. The rings have run 750,000 miles. All of our pistons are discarded at 1,500,000 miles. I don't know why we do that—they seem to be as good as when they started out. When we display the new piston the expert invariably says: 'That is no good.' We answer: 'How do you know it is no good—were you ever a piston in a Diesel?'

"In our work on the standardization of fuels we found at least 14 errors in the International Critical Tables because people have gone through the motions that should give you a pure material but didn't. Again, one of the experts said you couldn't have more than 100 octane fuel, but during the war we had 150. In fact, we now have 'Triptane,' with 500 performance.

"As to research laboratories, one sales department may say: 'Research is quite the thing. We ought to have a nice nickel-plated laboratory to which we can bring our customers and show them how good we are. I would sooner run a research laboratory with too little rather than too much money, because then you do more thinking and don't rely so much on the facilities.'

"An interesting question in metallurgy is the effect of small quantities. You know of our work on the annealing of malleable iron, where a thousandth of one per cent of tellurium reduces the time of annealing by 50%. We are sure that there are metals where the addition of a microscopic amount keeps it from corroding, or makes it corrode.

"I asked a fellow in the airplane business: 'Joe, how near up-to-date on changes did you get when you quit making airplanes?' He answered: 'I don't think we got any nearer than 10,000 changes of being caught up. But that was awfully good because one time we were 50,000 changes behind.' That they couldn't do in Germany. They couldn't get 100 changes behind and keep going."

"May I have 50 milligrams of uranium?"

U. S. Missions to Germany

Among our interesting "fan mail" in response to the "Production Frontiers" department for December, relative to U. S. technical missions into Germany, was a letter from a member of one of such missions. He says that "any number of times we were more than seven hours ahead of the infantry, and once or twice we were well ahead of the armor. In fact, General Patton sometimes censured some of the eager beaver technicians, asking them, please, to let the Army have 24 hours occupation before they moved in."

Our correspondent says there were indeed instances when our G. I.'s cooked their chow with German blueprints and sometimes displaced persons looted and ravaged out of sheer cussedness, but there was no serious trouble for the technicians. In fact,

what blueprints may have been ruined in one place were found in duplicate in several other places.

Thorough "Jerry" was pretty careful, usually, when he buried or sank information in mines to properly protect it from the corrosive influences and elements so that perhaps he himself could recover it at some more auspicious future date. Where the material was found damaged "Jerry" usually confided to the American technical missions where undamaged duplicates could be found.

There is considerable doubt whether all the hard work and hardship endured by our technical missions bore commensurate results. In many cases there was surprise that the Germans were, after all, such novices. "Jerry" was good in subsurface craft, electronics and certain limited phases of guided missiles, etc.

Had our operational problem been the same as "Jerry's," we would have reached the same conclusions, or possibly better conclusions, to the same problems in a much faster time and our methods would have been more along mass production lines. One must have respect for German data and thoroughness but they can't hold a candle to us for "know how" and final results.

This "master race" slogan has fallen more flatly than some of our own American slogans which went awry, such as: "Car in every garage and chicken in every pot." (Too often it has been: "The chickens are in the garage and the car has gone to pot.")

Magnesium Christmas

True, Christmas is past, at least the 1945 holiday, but since the Christmas spirit supposedly ever lives on (especially when the U. S. plays Santa to the rest of the world), it is perhaps still appropriate to reprint a few lines of poetry from a Christmas card received from T. W. Atkins, executive vice president, Magnesium Assn. It is the "Night before Christmas" poem, beloved by childhood, but brought up-to-date by Mr. Atkins. We'll jump into the middle:

They looked out the window and what should appear
But a *Magnesium* sleigh and eight tiny reindeer.

So light was that sleigh way up on the roof,
Not a shingle creaked—then we heard one tiny hoof.
"I knew it," said Santa, "I knew it, by gum,
Prancer's shoes should have been made of *Magnesium.*"

Santa carried his pack with the greatest of ease,
'Twas made of *Magnesium,* too, if you please.
The gifts he took out were sure to delight—
All of them durable, all of them light.

A wheelbarrow for Father, a sweeper for Mother:
Toboggan for Teddy, pair of skis for Brother.
Vanity for Jody, a lighter for Sis,
Bracelets and earrings to delight any Miss.

Pa said to Ma, "Poor Santa must be tired,
With a load like that, help should be hired."
But Santa just chuckled, he thought it great fun,
For his presents were all made of *Magnesium.*

Three Presidents

We have by now shaken hands with three Presidents of the United States. In what other country could a "little man" so intimately rub elbows with the Powers? Our first hand-shake was with President Harding. True, he was only a Senator then. We played slip horn with a 10-piece college orchestra that was touring the chautauqua circuit. One of our stops was Marion, Ohio. Harding was the local superintendent of the chautauqua. He had played cornet with the "Marion Silver Cornet Band" back in the Gay 90's. He wanted to meet our trumpeter and trombonist, the brass section of our orchestra. Somewhere we have a snapshot of Harding standing between us "brass."

After our afternoon concert we tossed horseshoes with Harding at the back of the chautauqua grounds. After our evening concert he took all ten of us to his home to which Mrs. Harding had brought ten local belles of Marion to meet us—or, as Emily Post insists, we met them. Happy days, those!

Our hand-shakes with the late Franklin Delano Roosevelt have previously been recorded in these columns.

Our No. 3 was Harry S. Truman at the middle of January. There was quite a gang of us editors in the ante-room, waiting to be called into the executive office of the White House. Some one—a Republican—nervously pulled the gag: "To err is Truman, to forgive divine." At length we filed into the round room. Mr. Truman stood in front of his desk (Roosevelt perforce always sat) and shook hands with us, one by one. Our first impression: Best-dressed President we've had. (Of course, he was once a haberdasher.) Our second impression was his military bearing, straight as a ramrod. (Again, of course, he had experience.)

He spoke for four minutes, but one never quotes the President. He doubtless made a good impression on all. Of course, the overwhelming personal magnetism of a Roosevelt comes in a President only once in a hundred years perhaps. Our Harry has a tremendous job. He needs the harmonious cooperation of 135,000,000 Americans. Harry alone can't do it.

See Here, Eleanor!

Our contemporary columnist, Eleanor Roosevelt, comments in newspapers of Nov. 14 on the government survey of our national resources, as first advocated by Bernard M. Baruch. Says Eleanor: "A survey of this kind seems to me important, but it is difficult to estimate what you can do in the future, since the work of our engineers and scientists is one of the unpredictable elements in the picture. None of us knows what substitutes may be found for resources which were considered vital in the preatomic age, and none of us knows what might be worked out by cooperation with other nations."

Now, Eleanor, don't we know, at least 95% complete, what resources and materials we'll be needing for any war emergency over the next 50 to 100 years? Don't you realize that most vital materials are those that are basic and that new materials are merely brought forth by mixing with other materials in new proportions and by processing by new techniques?

Let future scientists fashion the most incredible contraptions, they will still use the basic blocks to build these marvels. So, let's survey and store these basic materials and elements!

EDITORIALS

Non-Ferrous Metal Scarcities

One might have thought, when we finally licked metal shortages at about the middle of the war, that they would stay licked as far as peace days were concerned. However, copper, and to a greater extent, lead, are looming up as truly scarce and something for the engineers, designers and metallurgists to give heed to—planning, where convenient, the use of a substitute metal or material.

To many who lived through the first World War, shortages now seem fantastic. It will be recalled how copper was so superabundant after the first war that many producers had to work at only a fraction of capacity for many months, or until the large war surplus could be used up.

This time our copper consumption is far in excess of domestic production and imports. Canadian and Rhodesian copper are earmarked chiefly for British consumption, which leaves us only the South American supply for imports. At 12 cents per pound, the American market is not an attractive outlet for our southern neighbors. Since the first World War, the copper content of American mined copper becomes ever lower, and the time approaches when we may be a have-not nation as to red metal. Because of the cataclysmic effects of this second World War, the entire world is hungry for copper.

In lead, the stringency is even more severe. Early in this second war lead was one of the most abundant metals. But the situation seemed to change almost overnight. Lead was being used as a substitute metal in many instances. Moreover, highly mechanized armies called for tremendous quantities for storage batteries. It is understood that our Government stockpile of lead has shrunk to 75,000 tons as against 275,000 tons only two years ago. Our lead price of 6½ cents can't compete with the world price of 7 cents or more. Hence, Canadian, Mexican, South American and Australian lead tends to go to Europe instead of here.

And, as everybody knows, the tin shortage is still with us.

So, the wise planners of our national-prosperity-to-come had best give heed to the situation. Raising ceiling prices might help, though there is the danger that world prices would be raised accordingly and a vicious price circle would be set spinning. Perhaps the best solution is for us metal workers and metal users to be sparing in our uses. We can perhaps keep down alloy contents, or use substitute materials, or sometimes modify design to save or employ fabricating methods that permit the use of "available" materials. The significance of this whole situation to materials and process engineers is presented in Fred Peters' editorial in this issue, and we need do no more here than heartily agree that we did it in 1942 and 1943, and certainly we can do it now if we have to.

—H. A. K.

Air Express and the Materials Engineer

A comparatively new but rapidly growing phase of air transport is the use of air express and air freight. We have been told in Sunday supplements of the dawning of the new day, when tree-ripened or out-of-season fruits and vegetables would be flown to the big-city markets and appear on its tables the following day. Last October the first plane-load of fresh food was flown from California to New York. Air express pound-miles flown had risen from 3.6 billions in 1936 to 4.3 billions in 1938, 6.9 billions in 1940, 23.4 billions in 1942, and to 34.3 billions in 1944. The promise of an interocean air transport of perishable commodities such as fresh fruits has been held out for the immediate future.

Before this picture can become a large-scale everyday reality, however, the materials engineer must perform a few minor miracles. Perhaps the greatest single problem in the expansion of air express and air freight is that of lightweight but adequate packaging. The problem was the subject of much discussion at the Air Transport Meeting of the Society of Automotive Engineers at Chicago last December.

Air cargo, as outlined by the Air Transport Association of America, is of three general types: Unpackaged pieces to be stowed or tied down, such as machinery; packaged articles—bundles, bales, crates, or sacks; and fragile or perishable items requiring special attention.

It is the two latter categories that challenge the materials men. Tests have been made with paper and fabrics, molded plywood, plastics, and flyweight metals to provide suitable wartime containers. A crating material of thin plywood joined to fiberboard has been successfully used for many air transport packages. A strong, foldable, and moisture-resistant material resembling corrugated paper has been advocated for protecting odd-shaped pieces so as to eliminate oversize cartons and excelsior. Corrugated and solid fiber containers, light and weather-resistant, are a favored packaging.

Uniform standard containers to hold unpackaged articles are needed. They must be light in weight, as completely collapsible as possible, inexpensive, sturdy, and easy to handle.

For packing breakables such as glass or chinaware, new inexpensive shock absorbing materials such as sponge rubber are suggested. Indicative of the plans being made by aircraft companies is the report of experimental flights at 12,000 feet with live lobsters, oysters in the shell, crabs, and porgies, packed in weatherproof fiber boxes. At the other end of the list of olfactible cargo, flowers are being shipped in iceboxes made of coated fiberglass cloth.

The far-reaching results obtainable by better packaging materials and handling methods is shown by the Air Transport Association's estimate that about half the loss in speed of air transport is caused by ground time. More suitable containers will not only reduce the tare weight to be carried, but will cut ground time also.

While plywood, plastics, paper and fiberboard, cloth, and their composites are rightfully being given prominent consideration in this field for lightweight materials, surely there is a place for the lightweight metals. And even for the heavier metals with compensating higher strengths. The field is large and of growing importance. Materials men in the metalworking industries can make a contribution to air transport and to their own industry at the same time by producing suitable metallic containers. —K. R.

Steel is Still King

A fair appraisal of the achievements of the American steel industry during World War II can now be made. It is indeed an interesting one—one that every American can be proud of.

When the war clouds were gathering and when our aid to Great Britain and Russia took definite shape, demands for greater steel capacity became insistent and inevitable. In spite of dire predictions of failure, our capacity for steel ingots and steel for castings stood at the end of the war at close to 95,000,000 net tons—a remarkable expansion over the 81,619,500 tons as of Jan. 1, 1941. An equally impressive record was also made in pig iron.

The peak wartime output of steel was in 1944 at 89,641,600 tons. The production in 1945 was still very large at 79,745,581 tons or only about 11% under the record in 1944. For four years—1941 to 1944—American furnaces turned out from 82,000,000 to nearly 90,000,000 tons each year—an achievement never before equalled by this or any other country.

Still more impressive is the total steel output for the war period—1941 to August 1945. In that period about 400,000,000 tons was poured—a truly impressive volume. Undoubtedly it can be truly said that but for the contribution of the American steel industry to materiel for war, the Allies would have lost.

Looking to the future—it can hardly be expected that our peacetime steel demand will approach anything like the war outputs of 82,000,000 to 90,000,000 tons per year, but with a capacity close to 95,000,000 tons, it is not at all improbable that production in peacetime may very well exceed the previous peacetime record of 63,206,000 tons in 1929. Every indication points to a very large civilian demand when order is brought out of the present industrial chaos.

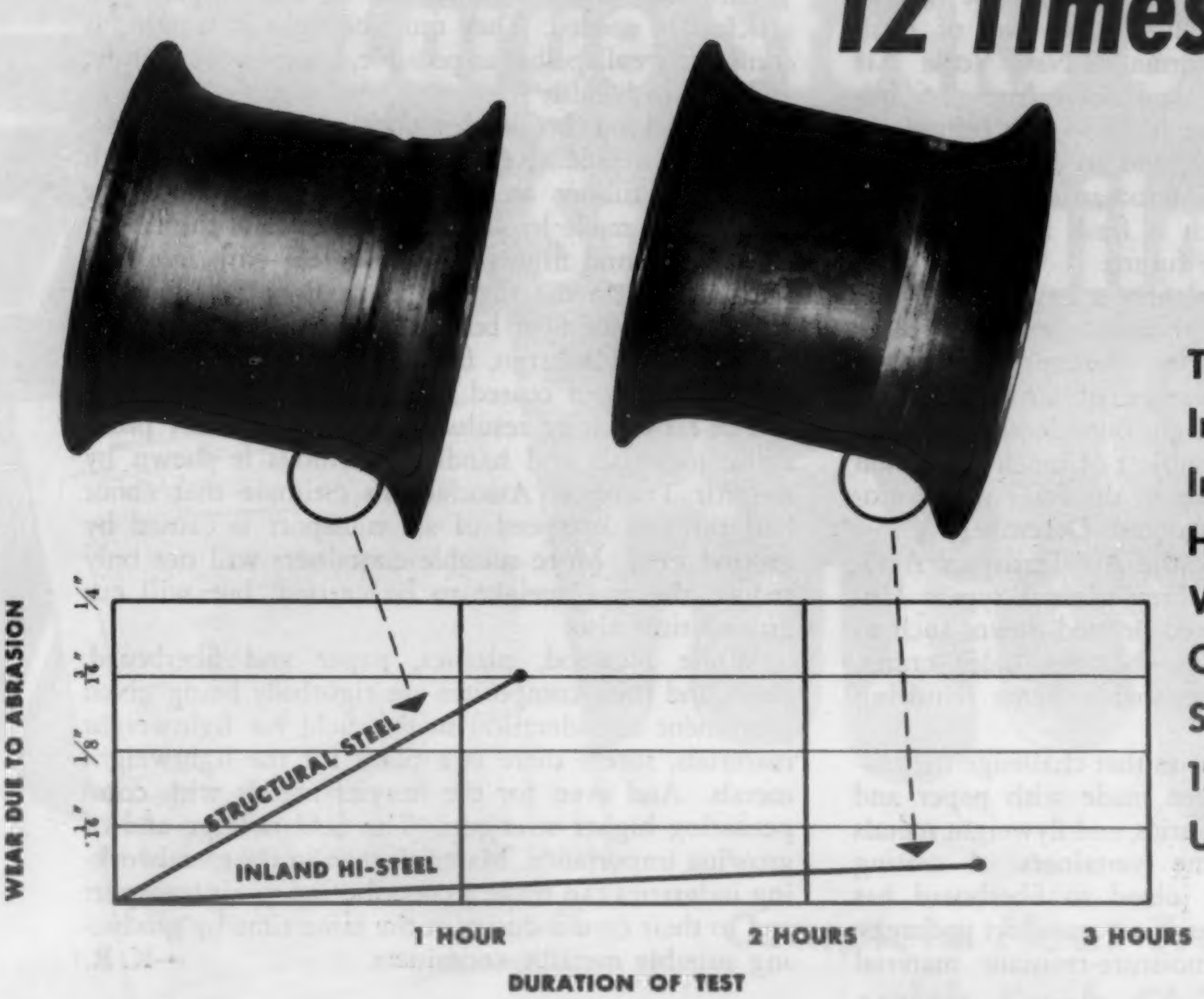
Steel has little to fear from competition with the light alloys, plastics or other materials. It is, as President Tower of the American Iron & Steel Institute said in a year-end statement, "still the cheapest, most abundant and most versatile of all metals. Its quality and usefulness are constantly being improved. Its industrial applications are wider than ever."

Steel is still king among the metals.

—E. F. C.

Resists Abrasion . . .

12 Times Longer!



Tests Show That Inland HI-STEEL,* In the Precipitation Hardened Condition, Will Outwear Ordinary Structural Steel More Than 12 Times When Used For Winch Heads

*TRADEMARK—REG. U. S. PAT. OFF.

Recent tests were undertaken by American Hoist & Derrick Co., St. Paul, Minn., to determine the comparative wearing qualities of winch heads—made of Hi-Steel in the precipitation hardened condition and of ordinary structural steel. To simulate actual field operation as closely as possible, the steel cable around the winch was held under load and the winch revolved. Both winch heads were of identical size and shape. In the first test of 70 minutes with ordinary structural steel, and in the second of 150 minutes with Hi-Steel (as indicated by the graph above), Hi-Steel's exceptionally higher resistance to abrasion was clearly demonstrated.

Along with superior resistance to wear, Hi-Steel also offers you a high strength steel—permitting considerable weight reduction while maintaining the required structural strength—as well as great resistance to fatigue, impact, and atmospheric corrosion.

Since Inland Hi-Steel can be furnished in most structural sections, plates, strip and sheets, and is economical to use, its applications are many and varied.

A partial list of products in which Hi-Steel is successfully used: Bins, Boats, Bolts, Booms, Bridges, Buckets, Busses, Chutes, Construction equipment, Conveyors, Cranes, Cyclone stacks, Locks, Floor Plates, Hoists, Hoppers, Material handling equipment, Mine equipment, Ore cars, Railway cars, Screens, Stacks, Structural framework, Tanks, Trailers, Trucks and Ventilators.

Write for the Inland Hi-Steel Engineering Bulletin No. 11. Inland Steel Company, 38 S. Dearborn St., Chicago 3, Ill. *Sales Offices:* Cincinnati, Detroit, Indianapolis, Kansas City, Milwaukee, New York, St. Louis, St. Paul. *Principal Products:* Bars, Structurals, Plates, Sheets, Strip, Tin Plate, Floor Plate, Piling, Reinforcing Bars, Rails, Track Accessories.

INLAND HI-STEEL

Materials Shortages Persist

an Editorial

One of our unexpected and mildly painful postwar problems has been the development of *shortages* of materials instead of the excess-capacity surpluses that we all glibly prophesied during the wartime expansion period. Where we expected severe postwar economic difficulties owing to an over-supply or over-capacity of light metals, copper alloys, lead, steels and castings, we are actually faced at present with widespread scarcities, and engineers responsible for the selection and processing of materials for our new peacetime products are going through the same sort of mental gymnastics in specifying materials that they performed in the 1942-1943 conservation and substitution era when practically everything was scarce.

Those who have studied, and especially those who have specified, the materigls engineering of the new 1946 automobiles are acutely aware of the extent to which availability has influenced the choice of materials used. The same is true of many other products, and informed opinion universally agrees that free engineering choice of materials, based on suitability for the intended purpose, workability and cost rather than on "what you can get," will not be the rule until near the end of 1946.

At present there are insufficient copper, lead, tin, rubber, castings (especially gray iron), steel, some types of plastics, and certain light metal products for the current needs and projected requirements of the metalworking industries. While this situation reflects the enormous pent-up demand for consumer goods and the materials to make them, it is to an even greater extent (with the exception of rubber and tin) the result of Government policies of one sort or another and the general political and industrial-relations bog in which we are now mired. As explained in Harold Knight's editorial in this issue, shortage of mine labor as well as Government import-price policies are responsible for copper and lead scarcities; gray iron foundries are beset with all the production-curtailing evils imaginable, from labor-shortage and absenteeism to unsatisfactory price ceilings; and the steel workers strike is, of course, the most crippling factor of all from the materials-supply (or any other) point of view.

These problems will not soon evaporate and indeed some we will have always with us. The situation is a real challenge to materials engineers and a real opportunity for them to exercise all their resourcefulness in specifying and applying available materials and forms where they can serve most effectively. For a few months at least we must "stretch out" our raw materials as we did in 1942 and 1943, and materials and process engineers who choose their materials and methods most efficiently from that standpoint will not only boost the immediate production of their own plants but will also serve to "spread around" the existing supply of those materials that are reasonably abundant.

Neither as individuals nor as a group can engineers dissipate the strikes or untangle the wages-prices-production snarls that keep badly needed materials from our plants. But we did learn how to use our available materials most efficiently once before and we should surely be able to do it again!

FRED P. PETERS

Right: Loading graph crucibles with copp rod for anode castin (Courtesy: Machle Laboratories, Inc.)

The operator is manipulating glass tubing in preparing parts for large tubes. (Courtesy: Machlett Laboratories, Inc.)

Some Materials and Methods for X-Ray and

by **CHARLES F. LINDSAY, PH. D.,** *Consulting Metallurgist, United States Testing Company, Inc.*

THIS ARTICLE IS not intended to teach the complete art of manufacturing vacuum tubes of the type specified, but is written in the hope that it will provide general information of interest and value. As far as the writer knows, there has been no attempt to publish any English information such as this, though in German there has been published the very complete and thorough work of Espey and Knoll, published in 1936 under the title of *Werkstoffkunde der Hochvakuumtechnik* by Julius Springer in Berlin, and re-published in this country, under authority of the Alien Property Custodian, by J. W. Edwards, Ann Arbor, Mich. It is impossible in an article of this length to completely cover in full detail all the materials as has been done by Espey and Knoll. The raw materials almost universally selected for tube manufacture are varied and the requirements are very specific and definite.

Materials used in the art of tube manufacture are numerous and include:

Glass for bulbs, tubulatures, anode and cathode assemblies and the like

Copper	Tungsten	Beryllium
Nickel	Tantalum	Molybdenum

Glass sealing alloys such as Kovar and/or Fernico

Oxides of the alkaline earths

Glass

The glasses used for these purposes are what is known as hard glasses, all of the general class, known as boro-silicate glasses—though in receiving radio tubes, incandescent lamps and the like, soft glasses are frequently used—and, in the case of X-ray tubes, this is almost universally the glass known as "chemical pyrex" or, to the trade, as Corning Glass Works Code No. 774. In the case of power tubes and rectifiers this glass is often substituted by Corning Glass Works "Nonex," Code No. 772. This glass contains a percentage of lead compounds in its composition and is, therefore, not used in X-ray tube manufacture because of the high X-ray absorption by glasses containing lead. These glasses are used because of their relatively high softening point, high resistance to thermal shock and general stability. In addition to those mentioned, other glasses are used for the manufacture of graded seals where the glass has to be joined to metal or other glasses and where, therefore, it is necessary to minimize the stress at any junction point. Glasses commonly used for this purpose are known as Corning Glass Works Code Nos. 7052 and 707 and, in some cases, Nos. 705 and 704, though these two latter glasses, while having proper

d Power Tube Manufacture

While some techniques are specialized, many materials and methods used in X-ray and power tube manufacture can be applied in other industries.

thermal expansion coefficients to warrant their use in making graded seals, are objectionable from the standpoint of chemical stability and are apt to develop a high percentage of crazing by devitrifaction of the glass giving the article an unsightly appearance through lack of transparency.

Most manufacturers, with the exception of the General Electric Company and, in some cases, the Westinghouse Electric Corp., who have their own glass plants, purchase these glasses in the form of bulbs, tubing and cylinders from one of the large glass manufacturers. For X-ray tube manufacture there is usually ground on the bulb at a specified point given by the user a thinner area for a window to decrease as much as possible X-ray absorption by the glass of the bulb.

Two of the most important requirements of vacuum tube manufacture are:

- A. Absolute cleanliness
- B. Freedom from inclusion of materials evolving gas at the temperature and vacuum under which they are required to operate.

The glass bulbs and tubes on reception at the plant are first given a visual inspection for faults such as blisters, small stones, striations and physical dimensions. Where the faults are minor and can be repaired at the plant, the bulbs are then worked over in the glass shop to remove these imperfections by melting them into the surrounding glass, and the bulbs and tubes thoroughly annealed thereafter. Where this is impossible, the bulbs and tubes which do not meet specifications are returned for credit. The bulbs after annealing are thoroughly cleaned on the inside by chemical means to remove surface stains and adhering matter.

The bulbs are washed thoroughly with hot running water followed by distilled water and then are ready for assembly with the proper parts which have been made ready in separate operations. The tubes are treated likewise, though in some cases the chemical treatment is omitted and only a thorough washing with water substituted.

Copper

Copper is used as anode material in nearly all types of modern X-ray tubes. Its choice for this service is governed by:

1. Its ability to be cast in gas free form.
2. Its very high thermo-conductivity which allows it to remove quickly the heat generated in the target by the electron bombardment, and thereby reduce the high temperature of

the tungsten target which is usually cast integrally with the anode.

If it were not for this heat removal, the targets would quickly come up to the melting point of the tungsten and ruin it.

In the manufacture of anodes, only copper of high purity can be used. Ordinary bar copper and the ordinary coppers of commerce, when cast, generate so much gas that the anodes are porous and, under the vacuum and the high temperature inside the tube, liberate so much gas that they are difficult to outgas and make the tubes formed from such coppers almost impossible to finish to the high standards required.

Certified oxygen free high conductivity—Certified OFHC—copper is the choice, though occasionally the manufacturer attempts to get by with well deoxidized copper. The preferred method of casting is in vacuum with exterior heat by high frequency coils. The tungsten target of proper size is stapled to a carbon block whose upper surface is cut to the angle desired for the target by the tube designer. This carbon block forms the bottom of a tubular mold and is inserted therein and held in place by a molybdenum wire cross rib.

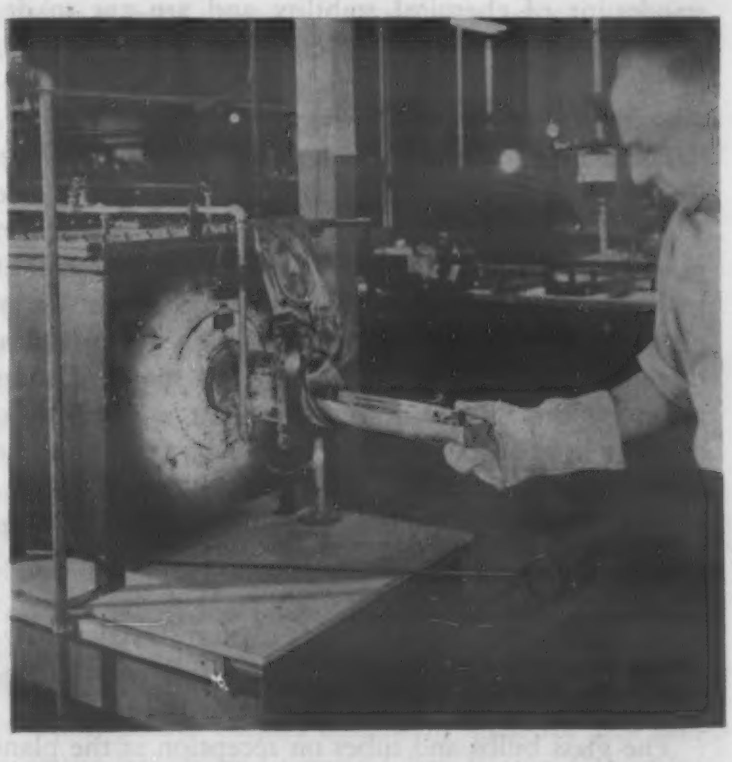
The mold is then filled with the exact weight of copper required and is suspended in a pyrex, or preferably "Vycor" vacuum bottle by wire suspension hooked in the top of the mold and hanging to the lip of the vacuum bottle. The bottles are sealed by ground joints lubricated with low vapor pressure grease. A high vacuum, at least 1×10^{-5} mm. of mercury, is then pulled on the bottle and its contents.

High frequency heating coils with flexible cables are then brought into position surrounding the vacuum bottle and covering the lowest part of the mold. High frequency current is then applied and the coil gradually raised until all of the copper is molten, filling the lower part of the mold. Power is then reduced and the coil so located that cooling starts at the bottom and the top kept molten as a reservoir of molten metal to fill in the shrinkage in the lower part of the ingot. Power and location of the coil must be so arranged that the metal cools gradually from the bottom up, and the last part to freeze is the top. When this is completed, the coil is removed from around the bottle and carried to the next bottle in order of work, and the process repeated. When the cast metal has cooled enough, the vacuum on the bottle is broken and the mold with contained ingot removed, and the ingot taken out of the mold. Usually this can be done without damaging the mold, and the mold used repeatedly. In this way the cast anode ingot has the tungsten target cast integrally with the anode and with the target either appearing on the surface as such or with only a film of copper over its surface. The anodes are now ready for machining and processing to required final shape. For a more extended account of this casting practice, the reader is referred to an article entitled, "Vacuum Casting of Electronic Parts" by Kenneth Rose on Page 1324 of METALS and ALLOYS, May, 1945.

Tungsten

Tungsten, in the manufacture of electronic tubes, is valuable because of its very high melting point, its extreme density, and its high atomic number. It is used as wire in the manufacture of X-ray tubes for hot filaments. For this purpose, it is usually wound as a small spiral on a mandrel and thereafter hydrogen annealed to set its shape. Most manufacturers buy tungsten as wire of specified diameter and quality. In the manufacture of X-ray tubes, only pure tungsten is used, but in power tubes where the emission required is much higher, thoriated tungsten is used. In these filaments, the tungsten powder prior to manufacture into wire is mixed with 1 to 2% thorium oxide and a binder such as gum tragacanth. These filaments in practice are subjected to a special treatment before being incorporated in the tube. In general, this special treatment consists of:

A. Anneal in hydrogen to set the filament properly.
B. Flashing in a vacuum bottle at high vacuum with a specified amount of high reducing power hydrocarbon such as acetylene. During this process the electric characteristics of the filament are closely watched and held to accurate requirements.
C. The filament is heated in high vacuum to a high temperature (3992 to 4172 F) for a

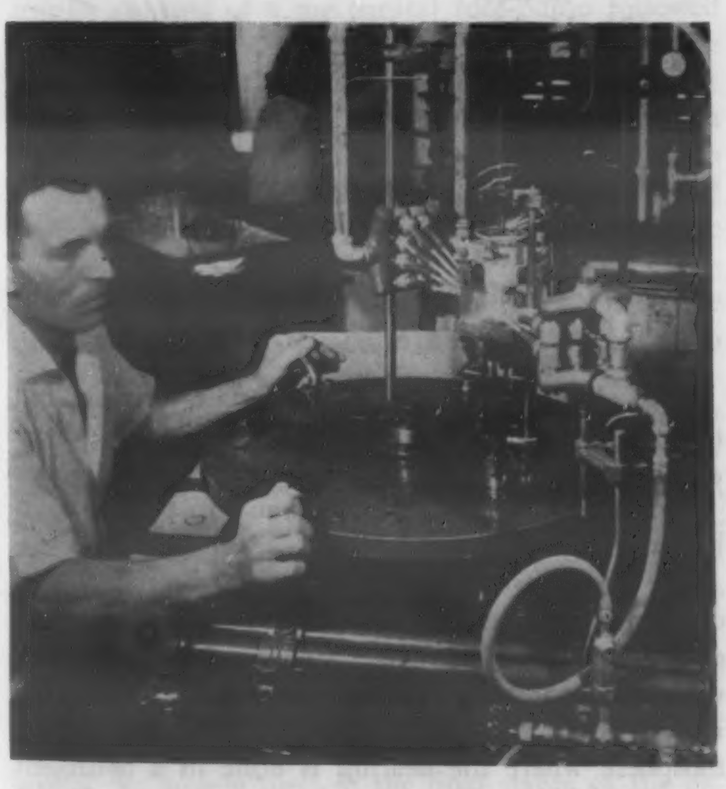


Removing annealed tungsten filaments from hydrogen annealing oven. (Courtesy: Machlett Laboratories, Inc.)

short time to vaporize a layer of metallic thorium to the surface. This operation must not be carried out long enough to boil the thorium out of the filament.

Such filaments have, at an operable temperature of say 1500 C (2732 F), several times the emission of a pure non-thoriated filament, and therefore, emit electrons sufficient to carry several times the current possible at the same temperature with pure tungsten filaments. Langmuir and his co-workers have shown that any increase in thickness over one molecular layer does not improve the emissivity of the filament. Burton and Kohl in their book, "The Electron Microscope," show—Page 179—that the emissivity at each point of the filament is proportional to the continuity of the thorium coating and publish diagrams of the emissivity of a filament accompanied by an electron microscope picture of the same filament paralleling the emissivity curve.

A third class of cathode is what is known as the indirect heated cathode of which the heating element is a pure thorium wire coiled on the inside of a small nickel tube, or tubes of other suitable material. In this case the tungsten wire is used only for its heating value and not for its emissive quality. The outside of the tube is coated with mixtures of the oxides of the alkali earths—calcium, barium and strontium. Mixtures of these oxides with a suitable binder are supplied by various manufacturers, each of which claim advantages. Only experiment can determine which mixture is the best for the special purpose intended. In X-ray tubes the cathodes are usually assembled in a metal part mounted in another metal part usually made of nickel, called the cathode head, in which the coiled spiral lies in a V-shape groove and is held in this position by the tails of the filament being carried through insulated holes in the cathode to the lead-in wires.



In this operation, glass is being fabricated with lead-in wires and support to form cathode stems. (Courtesy: Machlett Laboratories, Inc.)

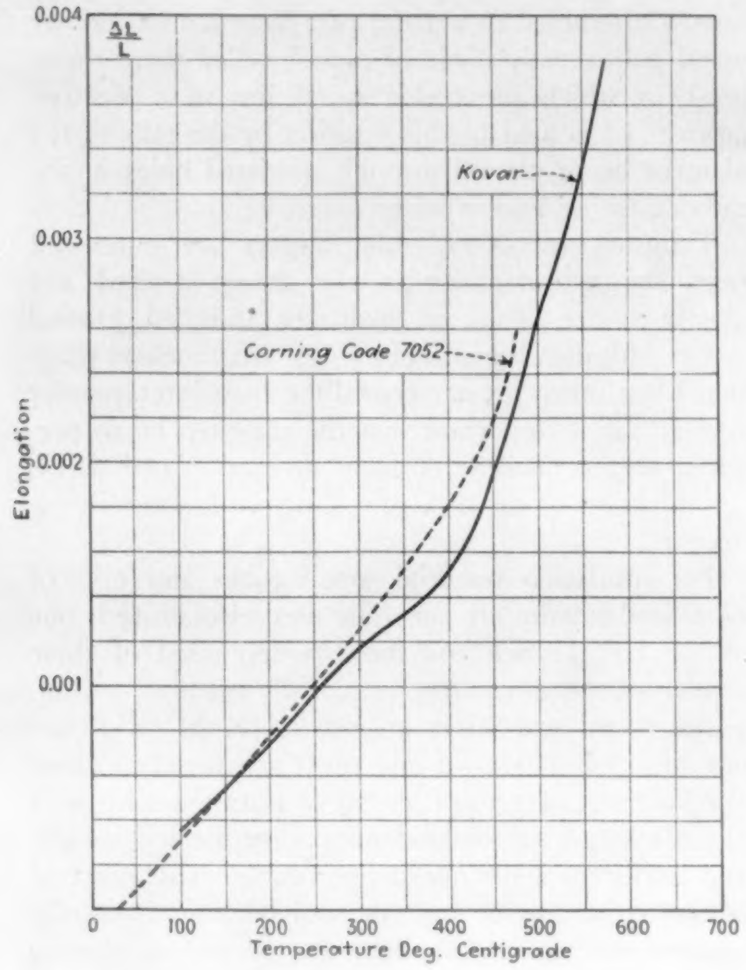
Tungsten for X-ray tube targets are purchased from the manufacturer in the shapes desired and closely to size. They are hydrogen ânnealed, ground and chemically cleaned before use. Inasmuch as tungsten has a much greater crystalline than intergranular strength, it is important that the tungsten be so prepared that crystalline surfaces do not extend across the thickness of the disk providing weak zones in the material.

For insulation material, small tubes and eyes of pure fired steatite are generally used. Isolantite is one of the best known and more widely used of these insulators. Lead-in wires are usually made of a composite form, and wires known as "Kuhl Grid" are one of the best known and most satisfactory. These wires consist of a short length of tungsten wire with a short length of molybdenum wire welded thereto and joined to a flexible copper cable. The junction between the copper and the molybdenum is usually covered with a small nickel collar to prevent flexing and breaking of the welded joint. The copper wires are usually nickel coated to prevent oxidation and unsightly appearance in the finished tubes, as these wires come through the tube and are exposed to the air. Sometimes wires of a dual material drawn from a composite ingot—copper inside nickel—are used for the same purpose.

Sealing-in Alloys

Because the envelopes of all X-ray tubes and most power tubes are of glass, it is necessary that all electric wires bringing power to the tube be brought through the glass. This involves making glass-to-metal seals and the avoidance, as far as possible, of dangerous stresses in so doing. Since, as has been mentioned, these glasses are usually what is known as hard glasses or the boro-silicate type, the coefficient of expansion of the lead-in wires must match the coefficient of expansion of the glass used.

Most metals and alloys have a straight line expansion curve while glasses have a bend in them in which above certain temperatures the expansion increases greatly. Fortunately, an alloy has been developed, known as "Kovar," which not only matches the coefficient of expansion of certain of these glasses but has a bend in its curve at approximately the same temperature as the glass, so it is possible at least in the case of one glass, namely Corning Glass Works Code No. 7052, to match the coefficient of expansion over the whole range of usual temperatures of the glass, i.e. from room temperature to approximately 450 to 500 C (842 to 932 F).



The coefficient of expansion of Kovar very nearly matches that of Corning Code 7052 glass so the two materials can be used together in making glass-metal joints.

Kovar was developed by the Westinghouse Electric Corp. (the same alloy is called "Fernico" by General Electric Co.). The composition of this alloy is approximately 54% iron, 27 nickel and 18 cobalt. This alloy in changing from the gamma to the alpha phase increases in expansion very markedly, but if manufactured properly and the composition is held closely to specifications, this transformation does not take place above a temperature of —80 C, so that it is possible to use this alloy under practically all working conditions. Average curves of No. 7052 glass and Kovar are shown on the accompanying graph.

Beryllium and Tantalum

Beryllium is the metal with the simplest of atomic structures and therefore is almost completely transparent to X-rays. For this reason it is used where possible as windows in X-ray tubes. Unfortunately pure beryllium is an extremely difficult metal to work, though by special treatment and remelting and casting in vacuum, beryllium can be and is being produced in a form that can with great care and special techniques be rolled. It will, in the writer's opinion, never be a really malleable or ductile element because of its lack of sufficient slip planes in its crystalline structure, but beryllium has been rolled to sheets or strips 0.004 in. thick, which held a very high vacuum for periods exceeding three years. It is usual practice to braze these thin beryllium windows to some other metal used in the construction of the tube.

Tantalum is used in vacuum tube manufacture usually on account of its high melting point and easy out-gassing properties as anodes in manufacture of targets for certain types of X-ray tubes where small focal spot is not a requisite and therefore the very highest melting point of tungsten is not required, for anodes in rectifying tubes and for plates in power tubes. It would have a wider use were it not for the high cost. It is much more easily worked into wire, sheet or plates than tungsten and can be obtained and is used in the form of wire, strip and plates.

The oxides of calcium, barium and strontium are excellent emitters of electrons at medium temperatures and are therefore used for cathodes in the type of emitter cathode known as the direct-indirect heated type in which the emitting material is applied to a surface, usually a cylinder of nickel, which is indirectly heated by a tungsten spiral which is used only as an electric heater and not for its emitting properties.

Methods

In the manufacture of vacuum tubes of the types being discussed the processes can be roughly divided into:

(1) Chemical treatment of raw material to produce a uniformly and completely clean surface.
(2) Machining or otherwise forming the parts into their required final shape.
(3) Pre-assembly of the required materials into parts for the tubes, e.g., cathode assembly, anode assembly, grid assembly, plate assembly, etc.
(4) Assembly of the pre-assembled parts into the envelope to make the completed tube.
(5) Exhaust.
(6) Test.

The cleaning of the raw materials, casting and machining of anodes and some of the processing have already been discussed.

It is usually considered undesirable to use fluxes in brazing or soldering processes. Specifically Kovar, above mentioned, is frequently used brazed to the copper anode with silver solder. This solder is preferably a 50-50 copper-silver solder, which is used to unit the Kovar to the copper. This is done quite often in an electric heated tunnel furnace with neutral atmosphere where the heating is done in a hydrogen atmosphere and the actual brazing in a nitrogen or sometimes forming gas atmosphere.

The exhaust of vacuum tubes is a most important

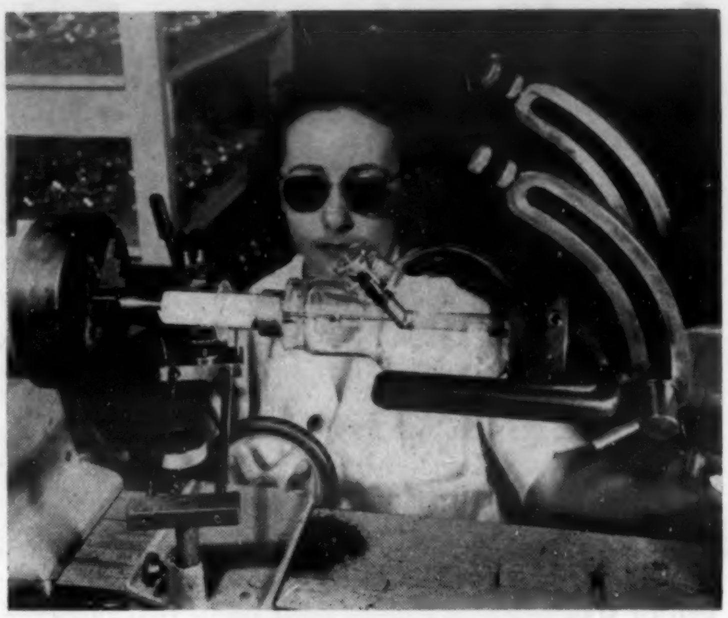
and highly complicated art. The exhaust usually consists of a number of steps. First, the tubes are sealed to a manifold—the number of tubes to any manifold varies with the size of the tube and may vary from 2 to 12 tubes being exhausted at the one time. After the tubes are sealed to the manifold and a relatively high vacuum has been pulled on them, the tubes are baked at as high a temperature as the glass will stand. This is usually in the neighborhood of 450 C (842 F). After baking, the ovens in which the manifolds are mounted with the tubes are allowed to cool.

The second step is usually a high frequency heating of the metal parts in the tubes.

The locations of the metal parts in the tube are successively surrounded by high frequency coils and power applied and the metal parts brought up to the highest possible temperature they can stand in order to effectively out-gas the metal parts. Care must be taken that the temperature to which the metal parts are heated is not so high that adjacent glass parts become heated to the softening point and allow the metal parts to collapse or distort the tube. Following the high frequency treatment the high frequency coils are removed and high voltage connections made to the tube. High voltage is gradually applied to the tubes in a series of runs and pokes and the voltage gradually built up to a voltage approximately the final voltage under which the tube is to be run. Filaments are also connected to low voltage supply and rheostat control and filaments given a conditioning run.

During all these operations the tubes of course are being continuously pumped. The pumping system usually consists of a mechanical fore-pump followed by a high vacuum diffusion pump using one of the very low-pressure oils at high temperature—as the medium. Usually during these processes an ionization gage is on the line and the current flowing through the ionization gage is systematically measured and watched. During the processes above outlined the current shown on the ionization gage will vary greatly, being up as high as 20 microamperes during the operation. In the manufacture of high-quality vacuum tubes it is usually necessary to repeat the above outlined operations two or three times. The current shown on the microammeter during the first round of operations will be wildly irregular; during the second will become more uniform and during the third the microammeter even at the start will rarely run above 3 microamperes, falling to 1, which is approximately equivalent in pressure to 1^{-6} mm.

After pumping operations are completed the tube is sealed off from the manifold and is ready for test. Up to this point no mention has been made of getters, which are largely used in the final stages of the exhaust to remove the very last traces of air. The getter proper usually consists of a pellet of barium or other effective agent mounted on a support in a side arm



A set-up such as this on the glass lathe is used to seal-in eccentric arms to bulb of a power tube. (Courtesy: Machlett Laboratories, Inc.)

to the tube and is flashed by high frequency, usually in the very late stages of exhaust procedure, though where the voltage under which the tubes are to operate is not high and the other conditions not too severe the getter is omitted. A great deal of study has been given to the subject of getters notably by the scientists of the Phillips Metallix Co. It is not possible to go into details here, for the subject is complicated and the ability to combine with oxygen to form a stable oxide at high temperature is not the only desired quality. To date, I believe, barium finds most general use, though tantalum, zirconium and titanium have desirable properties and find some use.

Testing

The testing operations on a tube are more than just plain testing because during the testing operation the tube is so treated as to improve its operating characteristics, make it more uniform and remove electrical disturbances. The testing operation usually begins with a visual inspection of the tube and the removal to the side arm, which is afterward sealed off, of any small particle of glass or metal which may have inadvertently been left in the tube. This is usually followed in the case of X-ray tubes by making a photograph of the focal spot size of the tube. Voltage is then applied to the tube beginning at relatively low voltages and the tube run at constantly increasing voltages up to and above the operating voltage of the tube. This voltage treatment is done in a series of time and instantaneous pokes while at the same time the electrical condition of the tube is recorded and studied. If, and as often happens, irregularities appear, the tube is given repeated dosage at low voltages until, as usually happens, the irregularities disappear.

Specifications and the Materials Engineer

by J. L. McCloud, *Ford Motor Co., Detroit*

The following article is based on a paper "Methods of Specifying Materials" presented by Mr. McCloud at the S. A. E. Annual Meeting, Detroit, Jan. 7-11.

Specifications are of concern to many people. They concern the manufacturer who has to produce goods to a definite standard; to the engineer who has to decide how things should be made; to the designer; the inspector; and even the salesmen of materials.

By what is probably ultra-simplification, the problem of specifications can be reduced to two phases—the writing of specifications and the application of specifications. Here we will be concerned principally with the application of specifications, only incidentally with the writing of specifications.

The importance of the proper application of specifications is not always properly recognized. The Federal Government has an imposing array of specifications covering all sorts of materials subject to government purchase. However, in writing alternate emergency specifications, at the beginning of the war, no qualification was made to indicate differences in working properties and properties involved. For example, steel rod was an emergency alternate for free cutting brass rod.

Who Applies Specifications

Designers in many companies have the assistance of well informed materials engineers. The dependence of designers on materials engineers varies according to the character of design. In the airplane industry it is necessary to utilize the maximum weight-strength ratio. This means that a stress analyst working with both the designer and materials engineer guides the choice of material as the weight-strength ratio limits materials availability.

In automobile and truck design with its highly competitive field, the cost factor is paramount. Cost can be increased only if improvement in performance, reliability, luxury or economy of production results.

The ideal materials engineer must know what materials are available and the cost effect of the material he specifies in his own shop (or that of his supplier). To know the cost effect, he must know the relative material cost and seek the assistance of the production engineer who will manufacture the finished part.

The Society of Automotive Engineers, the American Society for Testing Materials, The American Standards Association, The Federal Government as well as the Army and the Navy have compilations of specifications or what are in effect sets of specifications. Practically every firm which was the prime producer or original designer of a piece of war material had its own book of specifications. Too, practically every individual producer of automotive equipment has its own set of specifications.

To help the seeker through this welter of words, various codifications have been written to correlate insofar as possible the various specifications relating to individual materials, as for example Aluminum Co. of America's compilation of specifications on aluminum and aluminum alloys. The same thought has been carried out in some of the SAE standards, for instance the corrosion resistant steels. Such lists are of great value to the materials engineer, especially when it is of value to a concern to establish their own coding system for the convenience of engineers, purchasing and manufacturing divisions.

Qualifications of Materials Engineer

The fundamental qualification of a successful materials engineer appears to be that he has been working at his trade for a long time. This is best superimposed on a thorough grounding on materials through education. There must also be a wide, broad and deep strata of that type of learning obtainable only in the School of Hard Knocks—Experience. He should have an elephantine memory that will function automatically with such reminders as that in 1937 zinc die castings used on the exterior of cars lost their paint in a few months, and that this trouble was cured by giving the die casting a phosphate treatment before painting. He must have a fertile imagination and the faculty of seeing similarities, noting analogies and detecting differences between situations that now arise and situations previously encountered. In short, all the specifications ever written can only be the type used to express the result arrived at by the engineer's use of his own judgment.

As all engineering proceeds to the known from the

Specifications are important, but they mean little unless properly applied. Here are suggestions for their application.

Whether the product be airplane, automobile or simple gadget the designer, unless he is also a materials engineer, should rely on a qualified materials engineer to learn whether the materials he has chosen are satisfactory in all respects for their intended use. (Rendering Courtesy: Glenn L. Martin Co.)

unknown usually by graduated steps, engineers should not be slow to make full use of the information embodied in blue prints of parts which were successful in their day but are now becoming obsolescent from some cause. Designers sometimes think they should be able to open a handbook and find out that 1946 shock absorber arm should be made of an SAE 1035 steel forging heat treated to a Brinell of 255. He will find that information on the 1945 blueprint but that information has only an evanescent value and may never become standard engineering data for that very reason.

Opinion to the contrary, the day will never come when the designer can open the book and decide that rubber compound RSUP 47 is the proper material out of which to make the newly designed motor mount for the engine on the drawing board before him. He will have to ask the materials engineer.

Materials engineers, when they are not the designers themselves, should consult with the actual designers. As a design is conceived, the natural first thought is of what to make the part. A material engineer then discusses available materials and treatments and as the design emerges, it carries the chosen material as an integral part of the design. As proof of this cooperation, the material engineer indicates his approval of such material specified by signing the drawing as does the designer himself.

Some materials are easy to specify and relatively easy to check by the customer to see that the specified material is supplied.

We might, however, take a part such as a gear and use SAE 4620 steel. Protect us from such indefinite notes—not specifications—that say chrome-moly steel or steel forging. These are unfortunate abbreviations since the designer had a certain chrome-moly steel type in mind and thought, of course, he would be understood since he knew of only one type.

In the case of steel parts, we have a widely developed science of thermal treatments and we want this or that one used. We do not, however, have as definite specifications for these treatments as with the materials.

If our gear of SAE 4620 is to be carburized and hardened, we will, of course, want to specify to what depth it is to be carburized. Since we know that the gear cutter will have to work to dimensional requirements and we will not want to see these changes, we show specifications of what the heat treatment is. This must, of course, be given in such a way that manufacturing tolerance is allowed for the tolerance in the chemistry of the steel.

As to specifying steel by hardenability requirements, this will in most instances accompany the general type specification and will be of substantial value.

Some consider treatment specifications as separate requirements to be carried by reference on the part drawing. This is often less confusing and may be more convenient. Sometimes the treatment is not specified in detail even by reference and is covered by mutual arrangement between the engineers of the designing and producing groups. If, no matter how, they are a matter of record and reference, they will not become walking specifications carried under the hat of some supplying company or department.

There are many cases of specification by trial and error. Tests have to be made by laboratory fatigue methods on the parts themselves. Conclusions reached by these tests are the basis of final revision of the specifications for details in the design.

In conclusion, there are specifications available so that a material engineer can express his choice. The choice should be understandable and be used by the purchasing agent, the manufacturer, receiving inspection to the ultimate end that the design conceived with the material engineer is actually produced.

Materials in Action as Seen by the High-Speed

by **KENNETH ROSE,** *Engineering Editor,* MATERIALS & METHODS

THE OPERATION OF HIGH-SPEED machinery used for processing materials and the behavior of materials in high-speed equipment of various types frequently bring perplexing problems to the engineer—problems that are not easily attacked by the usual trouble-shooting techniques. In the operation of a punch press, for instance, the motions may be too fast to follow by eye, and when defective work is produced it is difficult to make an analytical study of the operation. Products containing high-speed mechanisms may show irregularity in functioning, and again the engineer must solve the problem with little help except his intuition, prior experience with similar problems, and trial and error.

Recently the aid of the high-speed motion picture camera has been enlisted by industry for problems of this type. Several cameras have been produced especially for the trouble-shooting engineer, and these constitute an important tool with which to attack many problems involving motions too fast to be followed and studied by the unaided eye.

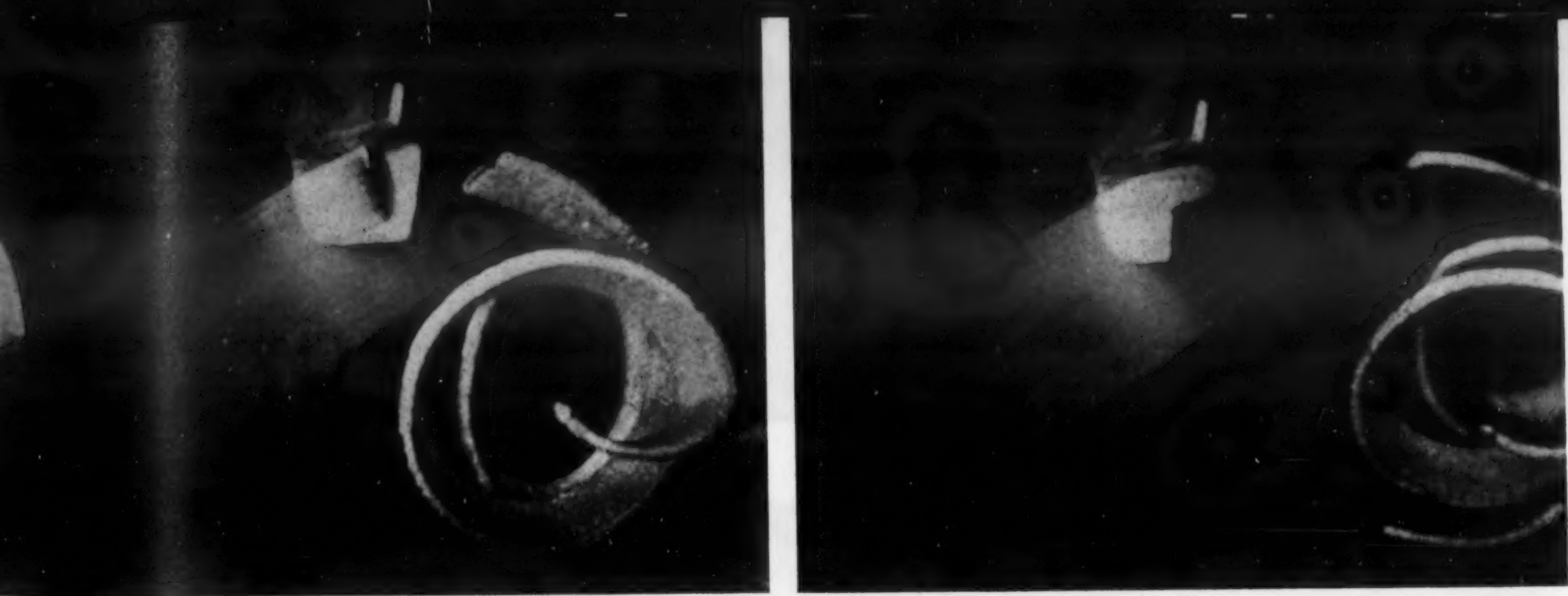
How and why materials behave as they do in certain operations can be determined by photography which is in effect "time magnification."

Workers in this field like to think of the high-speed camera as a time microscope, and the elapsed time for the duration of an event under study as magnified from a fraction of a second, perhaps, to the several minutes required for projecting the several thousand individual pictures, or frames, in the roll of film. Following this line of thinking, a camera taking 3,000 frames per sec. would have a "magnification" of 200 times when the film is projected at 16 frames per sec., and one taking 8,000 frames per sec. would enlarge the time interval of the event by 500 times. This makes possible a careful analysis of what is happening in the case under investigation, and in many cases leads to a solution of the problem.

Engineers studying the Izod impact testing of metals were puzzled by marks on fractured specimens indicating that more than one blow had been struck. The sweep of the hammer was too rapid to be followed by eye, but study of films made with the high-speed moving picture camera revealed that in some cases the dislodged portion of the specimen rebounded from the vise and was struck a second blow by the under edge of the hammer.

Study of chip formation with the high-speed motion picture camera in connection with the milling of steel helped to determine the most effective rake and clearance angles for the cutting tools.

Switchgear used in connection with dial telephone relays showed slight irregularities in operation. Study of the rapidly moving mechanism with the high-speed camera revealed a chattering of the switch, and the trouble was corrected.



Chip Formation

Movie Camera

Discloses Faulty Die Shape

Illustrative of a common type of problem and of the method of solution was the impact extrusion of condenser cans by Western Electric Co. Rapidly operating presses were producing defective work. The extruded cans were splitting, but operations were too fast for the eye to study the process. High-speed motion pictures were made of the operation, and studied by the engineers. Improper shaping of the male die was causing the trouble, and grinding a slight relief on this part eliminated the difficulty.

There are several basic conditions that limit the use of the high-speed motion picture camera in solving industrial problems. First is visibility. Internal operations cannot be photographed, and only rarely is it possible to construct a model in which the parts are visible while retaining all the characteristics of the original. When operations are external, but the parts to be studied are not sufficiently conspicuous, application of white paint to the part or the background will frequently provide sufficient contrast for photography. Arrangement of spotlights, reflectors, and similar devices will often solve problems associated with visibility, and several ingenious lighting techniques will be described later.

A second condition is accessibility. The field to be photographed must be such that it can be reached by the camera. The professional photographers and engineers making use of high-speed motion pictures have shown such resourcefulness, however, that it is difficult to find a situation in which the desired field is completely inaccessible to the camera. Arrangements of mirrors and reflectors have permitted the making of motion pictures of the human vocal cords during speech. The camera has been used in motorized equipment and in airplanes. Certainly a high spot in reaching the inaccessible was the taking of high-speed motion pictures of the drive wheels of a locomotive traveling 70 m.p.h. This project was undertaken by Timken Roller Bearing Co. in cooperation with a group of railroads. Test runs were made near Chicago, with the camera and lights mounted on a specially constructed frame beside the wheel, and a portable generator in one of the cars supplying power. Resulting pictures showed that the drive wheel in question was leaving the track at every revolution, and by a distance of 1½ in.

A third limiting condition is imposed by the heat generated along with the light used for illumination. This can be a serious problem. About 30 sec. will usually be required to light the subject, expose the film (about 1¼ sec.), and unlight. During this time the temperature may rise as much as 100 deg. Use of water cells or Aklo heat-absorbing glass as filters to reduce radiated heat was successful in many cases.

Pilot lights may be used for the focusing, and full illumination only for the actual exposure. "Trigger" lighting, in which the illumination is not used during the time the camera is accelerating, also cuts down the time during which heat reaches the subject.

The matter of setting-up and using the camera is described in the manuals supplied by the makers of the instrument. While the services of professional photographers specializing in industrial fields are available, the manuals are so written that engineers who are not skilled photographers have been able to use the camera successfully. The professional has

at his disposal a considerable quantity of auxiliary equipment, and knowledge of the particular techniques required to meet the problems of industrial photography. The engineer may acquire these techniques, and depend upon his ingenuity to meet other special conditions as they arise.

Lighting Presents Problem

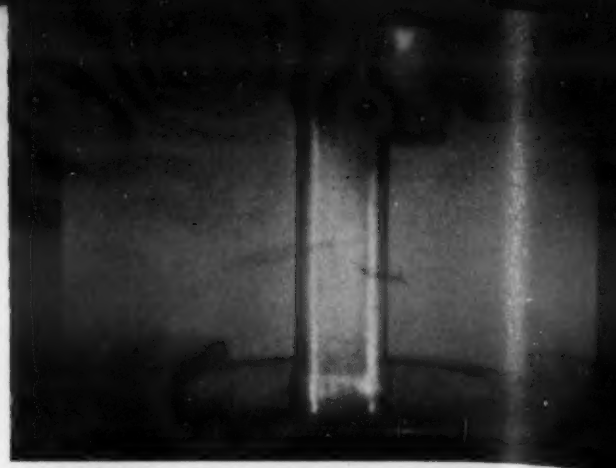
Lighting offers the most difficult problem in high-speed motion picture photography. Intense light is the first requirement. Until quite recently it was accepted as a rule that artificial light was *always* required for this type of picture-taking, even when the subject was in bright sunlight. Recently pictures have been taken at high speeds without artificial light, particularly at military proving grounds and in aircraft.

A trick in lighting was hit upon by technicians at Frankford Arsenal in 1943, and described by Painter and Huber, of General Motors, in a paper given at the annual meeting of the Society of Automotive Engineers at Detroit, Jan. 8 to 12, 1945. They used commercial sealed bulbs, GE PAR/SP-150, of the internally silvered spotlight type, and greatly intensified the light by stepping up the voltage with a transformer. A wiring arrangement permitted the use of normal voltage for focussing and adjusting, with a switch to increase the voltage from 120 to about 225 for actual photography. Increasing the voltage causes the light intensity to rise to ten times normal, while the life of the bulb is decreased to approximately one hr. From two to four bulbs are used to illuminate an area 6-in. square.

Lighting requirements can usually be met by such standard devices as spotlights or floodlights. However, for one case reported in which high-speed color photography was required, the immense amount of light needed was obtained by a device which fired 150 flash bulbs in rapid succession.

Accurate time determinations are a necessary part of high-speed motion picture work. While the speed of the camera can be controlled, such control is not accurate enough to provide the needed time reference. A simple device much used for this purpose is the argon lamp, in which the light alternates between halves of the lamp 120 times per sec. The lamp is placed in the photographic field. Tuning forks placed in the field serve a similar purpose. A marked disk revolving at constant speed and similar improvisations will provide a time reference to meet the needs of the individual case.

Most studies require a space reference also. This may be a mark on some stationary object in the field, a plumb line, a self-luminous point, etc. The space reference permits measurements to be made to determine abberations in movement of parts, unwanted changes of position, etc. Measurements can be made by projecting a greatly enlarged image of a single frame onto a screen and measuring directly from the space reference mark to the part in question. Sometimes the change in dimension will be obvious by simple visual inspection.



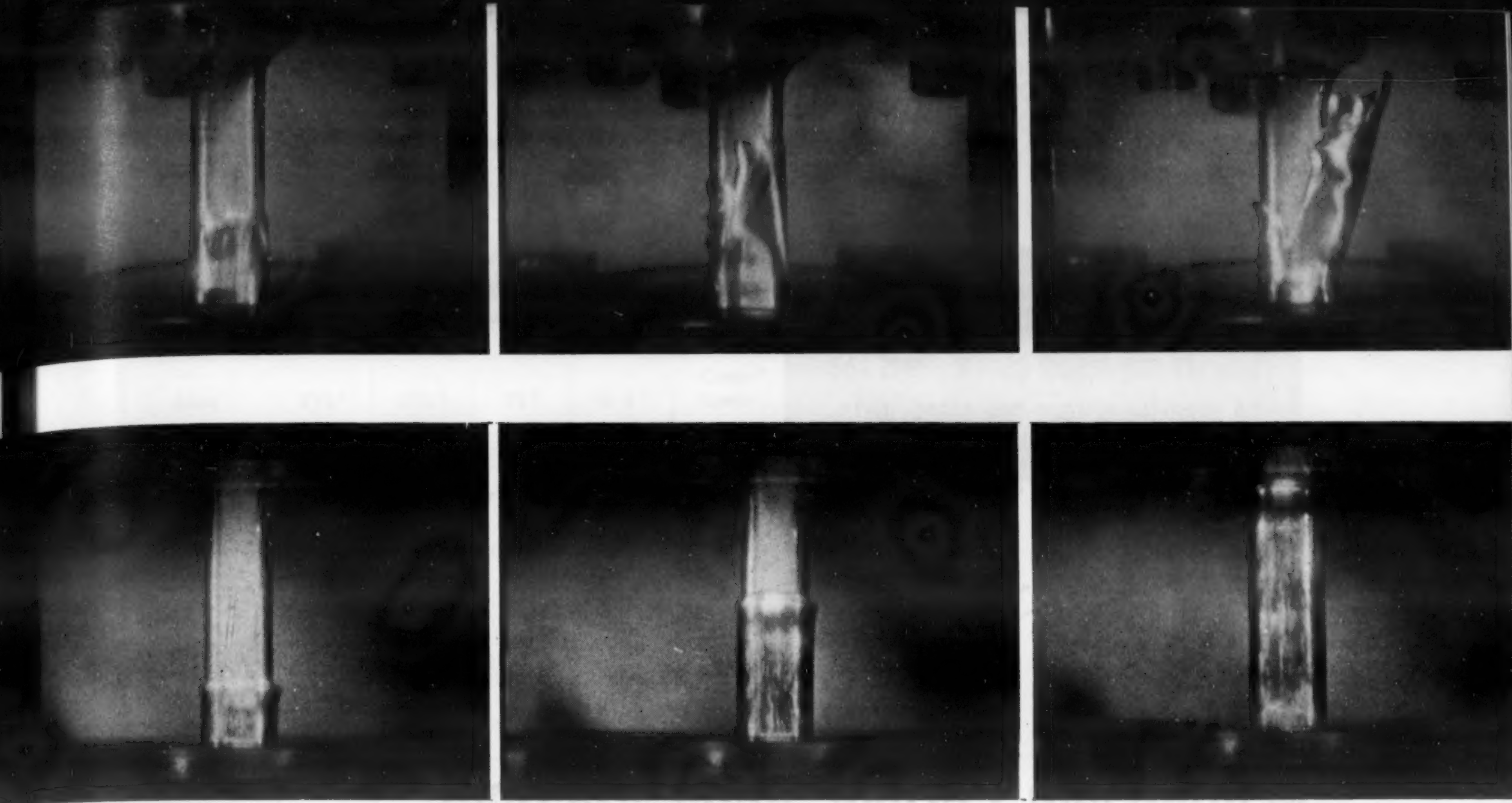
SEQUENCE A

SEQUENCE B

An example of the use of a space reference and also of set-up technique is found in a study of the hollow steel propeller blade. When turning at the rate of 35 revolutions per sec. a metallic sound was noticed in addition to the expected acoustic vibration. The high-speed camera was set up in front of the blade with an arrangement of mirrors to show the opposite side of the blade simultaneously. The camera was run at 2,500 frames per sec. Upon examining the film and making careful measurements from the space reference, it was found that the blade was actually collapsing so that the internal ribs were hitting. The fact was later confirmed by sawing through one of the blades.

At the Feders Company, Buffalo, a punch press forming machine gun clips at 85 strokes a min. was giving trouble. Erratic feeding of the strip stock was suspected. All moving parts of the machine were painted with reference lines, and the stock was marked off in quarter inches. Pictures were taken at 1000 frames per sec. The trouble was located in an incorrectly designed feeding cam.

While the cause of difficulties is sometimes clearly indicated by seeing the operation take place slowly, this is not always the case. It may be necessary to study the film frame by frame, projecting the pictures as stills. Another method is to make the film into a continuous loop and to run this without pause, perhaps for several hours, while the engineers study the operations. At other times the critical frames may be selected and enlargements made from these for careful, detailed study and measurement.



Studying pictures of faulty impact extrusion of condenser cans, engineers followed the flow of the metal on the punch. It was found that the metal was pulling to one side, as can be seen in sequence A taken from the film. Grinding of a slight relief on the punch cured the trouble. Proper working of the punch is shown in sequence B. (Courtesy: Bell Telephone Lab.)

Several Types of Cameras

The highly specialized cameras available for high-speed motion picture work number about half a dozen types. Of these only about three are in wide use for industrial work. An early type was produced by General Electric Co. for its own use and consisted of a series of small still cameras recording images on a sheet of film. While a succession of individual pictures resulted, they could not be projected as a motion picture.

The camera devised by Harold E. Edgerton remains open at all times, and pictures are made by an extremely rapid series of flashes from electronic tubes of the gaseous discharge type. The flash is from about 1/30,000 sec. to 1/1,000,000 sec. duration, and 12,000 pictures per sec. can be taken by this means. Produced by General Radio Corp., the camera is known as the Edgerton camera or as the G. R. camera. The electronic apparatus required is bulky and as much as several tons of equipment may be required for a setup. The camera uses 35 mm. film. Camera and equipment may cost from \$5,000 to \$50,000. It has found its principal use in the research laboratory rather than in industrial trouble-shooting.

Eastman Kodak Co.'s High-Speed Camera, Type III, uses 16 mm. film, weighs about 55 lbs., uses ordinary 110-v. current with speed control through a built-in rheostat, and sells for slightly less than \$1000. Speed control permits varying the rate of picture-taking from 500 to about 3,000 per sec. Film is used in 50- or 100-ft. rolls, and at top speed about 25 ft. of film is exposed during acceleration. The last few feet of film are destroyed by the speed of the mechanism.

The Fastex Camera produced by Western Electric Co., weighing 35 lbs., is made for 8-mm. or 16-mm. film. The former has a picture-taking range of from 300 to 8000 per sec., the latter from 150 to 4000. Speed control is obtained by voltage regulation, using 110 volt a.c. or d.c. About 40 ft. of the 100-ft. roll will be passed during acceleration when using highest camera speeds and chipping destroys the last few feet. While more pictures can be taken with a 100-ft. roll of the 8-mm. film than with the 16-mm., the resulting pictures do not permit enlargement to the same degree as the 16-mm. without losing detail. These cameras sell for about \$1400.

Both the Eastman and the Fastex cameras are satisfactory engineering tools with records of many thousands of feet of film taken in hundreds of industrial plants. Both are easily portable. Both are capable of meeting about 90% of industrial needs. Neither is intended for photographing ultra high-speed subjects for which the Edgerton camera is suitable. Both are simple enough in operation to be effective in the hands of the engineer.

Western Electric Co. has recently announced a 35-mm. high-speed camera taking up to about 3500 pictures per sec. While considerably more costly than the smaller cameras, it has the ease of manipulation that other Fastex cameras have. This may be added to the list of engineering tools in the future.

Properties at elevated temperatures indicate magnesium-cerium alloys can be used for pistons and other parts.

Magnesium-Cerium Alloy Castings for High Temperature Use

by R. F. MARANDE, *Dow Chemical Co., Midland, Mich.*

IN BOTH THIS COUNTRY and Germany extensive research programs have been carried out to develop magnesium alloys suitable for use at elevated temperatures. The investigations have covered various alloys in both the cast and wrought states. The 6%-cerium 2%-manganese magnesium alloy referred to as AM6 in German literature has interesting properties in both conditions. The binary alloy Mg-10Ce has exhibited even better properties in the cast state than AM6, particularly in regard to fatigue and creep at elevated temperature. This is probably related to its finer grained structure. Additions of manganese to the binary magnesium-cerium alloys tend to give somewhat coarser grain. Unless otherwise stated, cerium refers to mischmetal containing 96.8% rare earths of which 48.8% is cerium.

The major portion of this article will be devoted to a detailed discussion of melting and casting methods that have been found necessary in handling the magnesium-cerium alloys in the foundry. Some properties and uses are mentioned to illustrate the successful use of these alloys in high temperature applications. These magnesium-cerium alloys will be designated by the A.S.T.M. symbols EM62 and E10. These designations follow from the compositions: cerium, 6% and manganese, 2%; cerium, 10% and manganese, 0%, wherein the letter "E" represents the cerium containing alloys.

Properties of various magnesium and aluminum base alloys are given in Tables I and II. Based on creep data, the cast alloys would be expected to perform best at temperatures above 400 F, while below 400 F the wrought alloy has better properties. Properties at elevated temperatures approach closely enough to those of the aluminum base alloys now in use to indicate that many parts could with proper design be converted to magnesium-cerium alloys at a saving in weight.

Magnesium-cerium alloys containing approximately 6% cerium and 2% manganese have been found on the German aircraft engine BMW-801 D. One accompanying illustration shows a forged supercharger impeller taken from a German plane shot down over England. Another shows a rear cam followers guide and housing of the same (EM62) composition.

Many types of pistons have been cast and forged with the 6% cerium alloy and many have been cast with the 10% cerium alloy using practically the same design as had been used for aluminum pistons. Among these is the type shown in Fig. 3 which was given an

TABLE I

Mechanical Properties of Various Magnesium Base and Aluminum Base Casting Alloys at Room and Elevated Temperatures

Alloy	TYS [b]	CYS [b]	TS [b]	% E [a]	Creep [b] Limit	Fatigue [b] 10^6 Std.	10^6 N	10^6 NE	10^8 Std.	10^8 N	10^8 NE
Room Temperature											
H-HTS	17.8	18.9	38.7	7.6		20.8	14.3	0.69	15.0	9.5	0.63
EM62-HTA	16.3	17.4	19.3	0.5		12.0	12.0	1.0	7.0	5.0	0.72
E10-HTA	—	21.5	16.0	0.0		14.0	10.5	0.75	10.5	8.0	0.76
142-T61	32.0	—	37.0	0.5		20.0	15.0	0.75	9.0	8.0	0.89
355-T6	25.0	—	35.0	2.5		23.5	20.0	0.82	9.0	9.0	1.00
300 F											
H-HTS	14.2	17.7	27.0	40.3	4.3	13.6	10.0	0.74	9.4	5.0	0.53
EM62-HTA	13.9	15.5	16.3	2.0	17.0	11.5	10.0	0.82	8.5	5.5	0.65
E10-HTA	18.2	22.4	20.1	1.0	20.0	13.0	10.0	0.77	9.0	6.8	0.76
142-T61	28.0	—	30.0	0.5	—	18.0	15.0	0.83	9.5	7.5	0.79
355-T6	25.0	—	30.0	1.5	—	20.5	19.5	0.95	10.0	8.0	0.80
400 F											
H-HTS	12.0	—	17.5	—	—	—			—		
EM62-HTA	13.9	15.0	17.7	2.0	8.4 [c]	11.0			5.0		
E10-HTA	18.4	20.5	21.3	1.5	11.2	11.5			10.0		
142-T61	25.0	—	27.0	—	18.6	13.5			6.8		
355-T6	9.0	—	13.0	12.0	6.0				—		
500 F											
H-HTS	9.0	—	12.0	—	—						
EM62-HTA	11.3	14.7	17.1	4.5	4.2 [c]						
E10-HTA	10.2	—	16.7	2.0	4.9						
142-T61	5.0	—	12.0	—	—						
355-T6	5.0	—	8.0	22.0	3.6						
600 F											
H-HTS	3.7	5.9	7.3	77.2	—						
EM62-HTA	9.5	10.7	15.0	21.0	2.4 [c]						
E10-HTA	7.4	—	15.5	10.0	2.0						
142-T61	3.5	—	7.5	3.2	1.8						
355-T6	3.5	—	6.0	30.0	1.4						

[a] *in 2 in.*
[b] *1,000 p.s.i.*
[c] *SCS = Sand cast and stabilized*

Definitions: *Creep limit = Stress for 0.1% extension in 100 hr.*
Fatigue = R. R. Moore Rotating Beam
Std. = Standard Specimen
N = Notched specimen, SCF = 2; round notch, r = 0.1 d.
NE = Notch efficiency; strength notched ÷ strength unnotched.

Note: Dowmetal H-HTS was not held at testing temperature for a long period of time prior to testing.

experimental run in a large engine. The photograph illustrates the gating method that has been found most satisfactory for magnesium-cerium alloy pistons. Fig. 4 shows a motor-cycle piston with a cast in steel strut. Slot gates as shown in Fig. 3 were used.

The magnesium-cerium pistons described above showed a saving in weight of about one-third over conventional design in aluminum alloy. Clearances were made about one-third larger than normal at room temperature to take care of the higher coefficient of expansion of magnesium. To avoid stress concentration at the base of the ring lands, the ring grooves were machined with a semi-circular section at their root.

A 22-hp., 2-cycle engine has been operated at 4500 r.p.m. with sand cast EM62 pistons with complete success. Other service trials have given promising results.

TABLE II

Mechanical Properties of Various Magnesium Base and Aluminum Base Wrought Alloys at Room and Elevated Temperatures

Alloy	TYS [b]	CYS [b]	TS [b]	% E [a]	Creep [b] Limit	Fatigue [b]					
						10^5			10^8		
						Std.	N	NE	Std.	N	NE
Room Temperature											
0-1HTA	39.5	26.8	52.9	4.5	22.0	26.2	15.2	0.58	16.0	9.5	0.59
M [c]	30.9	—	39.6	7.6	16.5	17.2	10.0	0.58	11.0	6.0	0.55
EM42	27.1	—	37.0	8.0	—	22.2	13.5	0.61	15.0	6.0	0.40
18ST	47.0	—	63.0	17.0	—	33.5	21.4	0.64	18.0	8.4	0.47
300 F											
0-1HTA	20.7	19.2	31.0	30.3	2.8	20.5	10.8	0.53	10.5	5.0	0.48
M [e]	15.7	—	21.3	18.7	8.7	—	—	—	—	—	—
EM42	21.5	—	27.2	13.8	21.0	19.0	10.2	0.54	15.0	6.0	0.40
18ST	44.0	—	49.0	10.0	25.0	26.5	17.0	0.64	13.5	9.0	0.67
400 F											
0-1HTA [c]	14.7		21.6	49.0	—						
M [c]	11.7		18.8	25.0	—						
EM42 [c]	17.0		21.0	16.0	6.5 [d]						
18ST	15.0		20.0	26.0	13.0						
500 F											
0-1HTA [c]	7.8		13.6	83.0	—						
M [c]	7.5		13.0	60.0	—						
EM42 [c]	11.1		17.4	39.5	1.7						
18ST	7.0		11.0	32.0	—						
600 F											
0-1HTA [c]	4.7		8.7	123.0	—						
M [e]	5.4		9.0	70.0	—						
EM42 [c]	3.4		7.7	183.5	0.2						
18ST	3.0		5.0	65.0	1.6						

[a] *in 2 in.*
[b] *1,000 p.s.i.*
[c] *Extruded; those not noted are forged*
[d] *Stabilized at 400 F (24 hr.)*
Definitions: See Table I

Note: The magnesium alloys were not held at testing temperature for a long period of time prior to testing.

TABLE III

The Effect of 310 Flux on the Loss of Cerium During Alloying, Holding and Remelting

	% Flux Used	Temperature F		Chem. Analyses Total Rare Earths				Spect. Mn	Alloy Effic. %	Loss Ce on Holding %	Loss Ce on Remelt %	Total Ce Loss %
		Alloying	Holding	Nom. % Ce	Immed.	Hold 1 hr.	Hold 2 hr.					
No. 1												
After Alloying	5.4	1300	1300	8	6.98	6.49	5.98	2.1	87.3	13.5	—	—
After 1st Remelt	6.1	—	1300	—	4.69	3.99	3.55	2.0	—	27.1	22.3	—
After 2nd Remelt	7.3	—	1300	—	2.69	1.98	1.49	1.9	—	43.2	21.4	—
After 3rd Remelt	7.0	—	1300	—	0.99	0.68	0.57	1.8	—	50.5	35.3	92.8
No. 2												
After Alloying	3.7	1300	1400	8	7.26	6.42	5.90	1.8	90.8	17.1	—	—
After 1st Remelt	4.5	—	1400	—	5.18	3.91	3.33	1.8	—	40.2	14.0	—
After 2nd Remelt	7.1	—	1400	—	1.96	1.23	1.16	1.8	—	43.4	36.8	—
After 3rd Remelt	6.9	—	1400	—	0.73	0.44	0.17	—	—	83.6	34.2	98.4

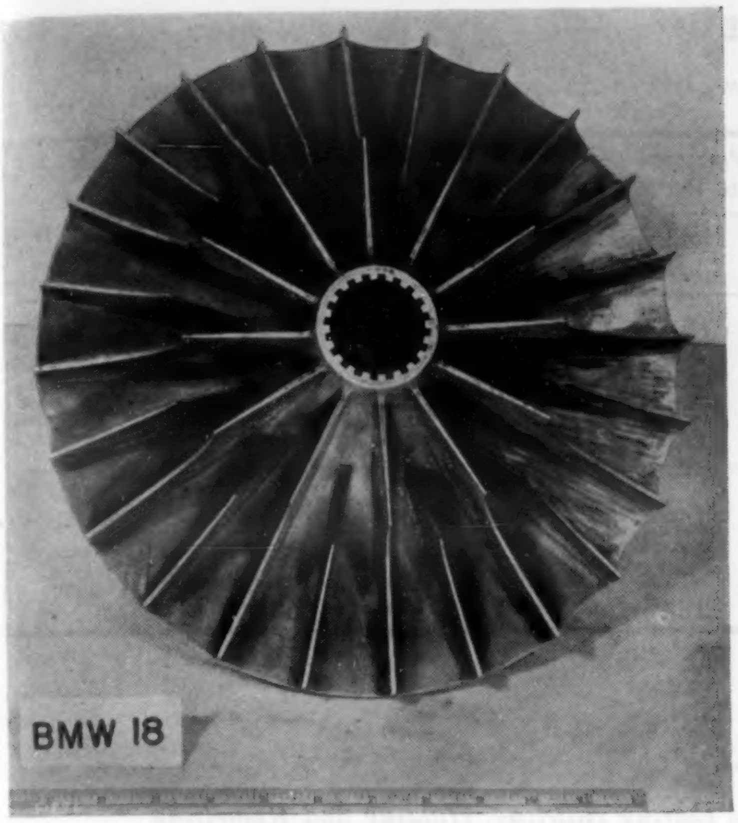


Fig. 1. This forged supercharger impeller found on a German aircraft engine is made of a magnesium-cerium alloy.

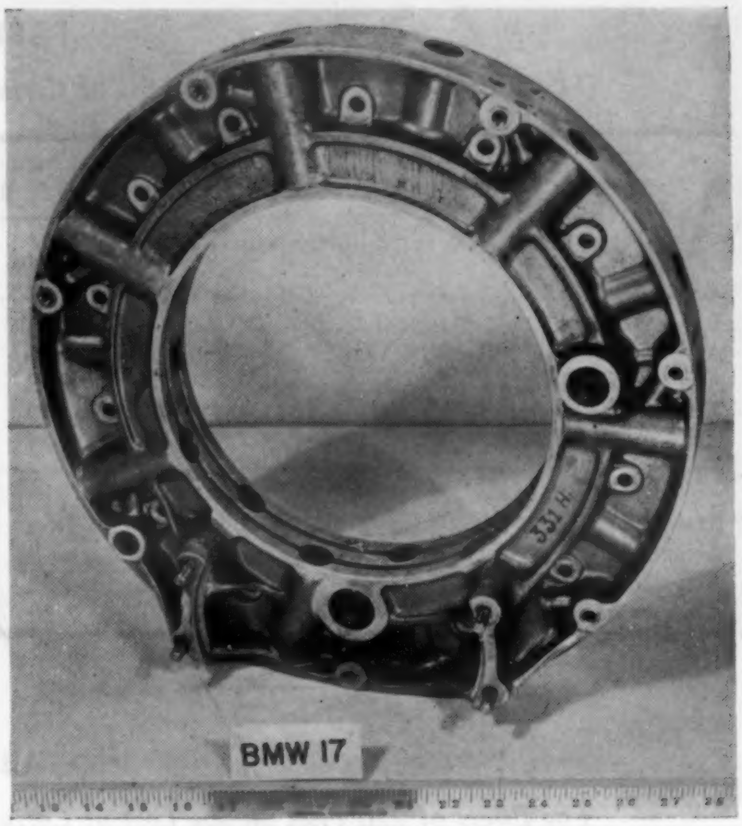


Fig. 2. The high temperature properties of magnesium-cerium alloys were utilized in the rear cam follower guide on a German aircraft engine.

Pistons illustrate a very severe application for magnesium-cerium alloys due to the wear involved as well as the high temperature. The satisfactory results obtained with such alloys, even under these conditions, suggest their successful use in locations subjected to high temperature but not involving wear.

Previous literature (1 to 7 inclusive, in bibliography) emphasises the importance of the flux composition used in melting and pouring magnesium-cerium alloys. Other references (8 to 10 inclusive) present data on magnesium-cerium and magnesium-lanthanum alloy systems.

Efficiency of Fluxes

Considerable work in this laboratory has been directed toward finding the proper flux, determining the alloying efficiency of cerium and developing a suitable melting and alloying technique. In this investigation Mischmetal was used as the addition agent for cerium. The alloying efficiencies shown are based on the total weight of Mischmetal added. It should be remembered, however, that Mischmetal contains only 96.8% total rare earths. Therefore, an alloying efficiency of 96.8% would be 100% if based on actual rare earths added.

The fluxes referred to in this paper are Dow 230, 310, and 220. The two former contain magnesium chloride ($MgCl_2$) while the latter contains no $MgCl_2$. Details of compositions, characteristics and methods of using these fluxes are covered by Nelson[11] in "The Melting and Refining of Magnesium."

The fact that $MgCl_2$ contributes to the loss of cerium was soon substantiated. It was also found that the introduction of cerium chloride ($CeCl_3$) to the flux is a rather impractical method of preventing loss of cerium at the present time due to the difficulty of obtaining anhydrous $CeCl_3$ and of keeping it anhydrous after it is obtained.

To handle the cerium alloys commercially it is necessary to know quantitatively how much cerium will be lost with various fluxes and with various melting procedures. The effect of using 310 and 230 flux for alloying and holding the cerium alloys is shown in Tables III and IV respectively. The alloying efficiencies are between 85.8 and 95.1%. The lowering of the cerium after 1- and 2-hr. holding periods is shown in the horizontal rows under "Chem. Analyses." The vertical columns illustrate the effect of remelting one, two, and three times respectively. Under appropriate headings the cerium loss on holding, on remelting, and the total cerium loss, using 310 flux is given in Tables III and IV.

The total percent of cerium lost when using 310 flux for remelting the same metal three times and holding 2 hr. each time is between 93 and 98%. In the case of the 230 flux the total cerium lost is somewhat lower, between 53 and 77%. The difference

TABLE IV

The Effect of 230 Flux on the Loss of Cerium During Alloying, Holding and Remelting

	% Flux Used	Temperature F		Chem. Analyses Total Rare Earths				Spect. Mn	Alloy Effic. %	Loss Ce on Holding %	Loss Ce on Remelt %	Total Ce Loss %
		Alloying	Holding	Nom. % Ce	Immed.	Hold 1 hr.	Hold 2 hr.					
No. 1												
After Alloying	4.0	1300	1300	8	6.86	6.54	6.43	1.9	85.8	6.3	—	—
After 1st Remelt	4.5	—	1300	8	5.82	5.42	5.06	1.8	—	10.1	9.5	—
After 2nd Remelt	4.7	—	1300	—	4.69	4.30	4.15	1.8	—	8.5	10.3	—
After 3rd Remelt	4.4	—	1300	—	3.95	3.62	3.37	1.7	—	17.7	7.9	52.7
No. 2												
After Alloying	3.0	1300	1400	8	7.61	7.16	6.89	1.9	95.1	12.9	—	—
After 1st Remelt	4.5	—	1400	—	6.08	5.51	4.95	1.8	—	20.1	8.3	—
After 2nd Remelt	5.3	—	1400	—	4.06	3.31	3.18	1.8	—	28.3	16.5	—
After 3rd Remelt	6.3	—	1400	—	2.70	2.18	1.92	1.8	—	35.5	7.2	77.2

TABLE V

The Effect of 220 Flux on the Loss of Cerium During Alloying, Holding and Remelting

	% Flux Used	Temperature F		Chem. Analyses Total Rare Earths						Alloy Effic. %	Loss Ce on Holding %	Loss Ce on Remelt %	Total Ce Loss %
		Alloying	Holding	Nom. % Ce	Immed.	Hold 1 hr.	Hold 2 hr.	Last Pig.	Spect. Mn				
No. 1													
After Alloying	9.3	1300	1300	8	6.80	6.85	6.77	6.80	—	85.0	.0	—	—
After 1st Remelt	5.6	—	1300	—	6.60	6.68	6.66	6.39	—	—	3.2	2.9	—
After 2nd Remelt	6.9	—	1300	—	6.21	—	5.99	6.14	1.8	—	1.1	2.8	—
After 3rd Remelt	—	—	1300	—	5.65	5.54	5.59	5.66	1.7	—	.0	8.0	16.8
No. 2													
After Alloying	6.5	1300	1400	8	7.17	7.17	7.10	7.13	2.0	89.6	0.6	—	—
After 1st Remelt	4.5	—	1400	—	6.76	6.77	6.58	6.77	2.1	—	.0	5.5	—
After 2nd Remelt	4.6	—	1400	—	6.45	6.31	6.40	6.36	2.0	—	1.4	3.4	—
After 3rd Remelt	7.1	—	—	—	6.31	6.22	6.25	6.19	2.0	—	1.9	0.7	13.7
No. 3													
After Alloying	6.1	1400	1300	8	7.34	7.21	7.15	7.25	1.9	91.8	1.2	—	—
After 1st Remelt	4.9	—	1300	—	7.05	6.91	7.01	6.90	1.8	—	2.1	2.3	—
After 2nd Remelt	4.8	—	1300	—	6.61	6.55	6.51	6.56	1.9	—	0.8	4.2	—
After 3rd Remelt	4.9	—	1300	—	6.23	6.33	6.40	6.25	1.9	—	.0	5.2	14.9
No. 4													
After Alloying	6.5	1400	1400	8	7.24	7.01	6.96	6.99	2.1	90.5	3.4	—	—
After 1st Remelt	4.7	—	1400	—	6.67	6.23	6.26	6.34	2.0	—	4.9	4.6	—
After 2nd Remelt	4.8	—	1400	—	6.09	6.01	6.00	6.00	1.9	—	1.5	3.9	—
After 3rd Remelt	5.1	—	1400	—	5.69	5.22	5.15	4.98	1.8	—	12.5	5.2	31.2

may be accounted for by the lower $MgCl_2$ content of the latter flux. However, the loss of cerium in either case would be prohibitive in commercial operation.

The Effect of Magnesium Chloride

No. 220 flux was originally developed for use in the sulfur dome die casting pot, and was designed to refine the metal and sink to the bottom of the pot without providing any surface protection. In melting cerium alloy, however, a larger amount of flux is used so that, although a portion of the flux sinks to the bottom, a sufficient amount remains on the surface to afford protection.

The data on alloying, holding, and remelting using flux containing no $MgCl_2$ are shown in Table V. The alloying efficiency of cerium ranges from 85 to 91.8%.

Fig. 3. Recommended gating and risering practice for magnesium-cerium alloys is shown on this 5½-in. dia. piston.

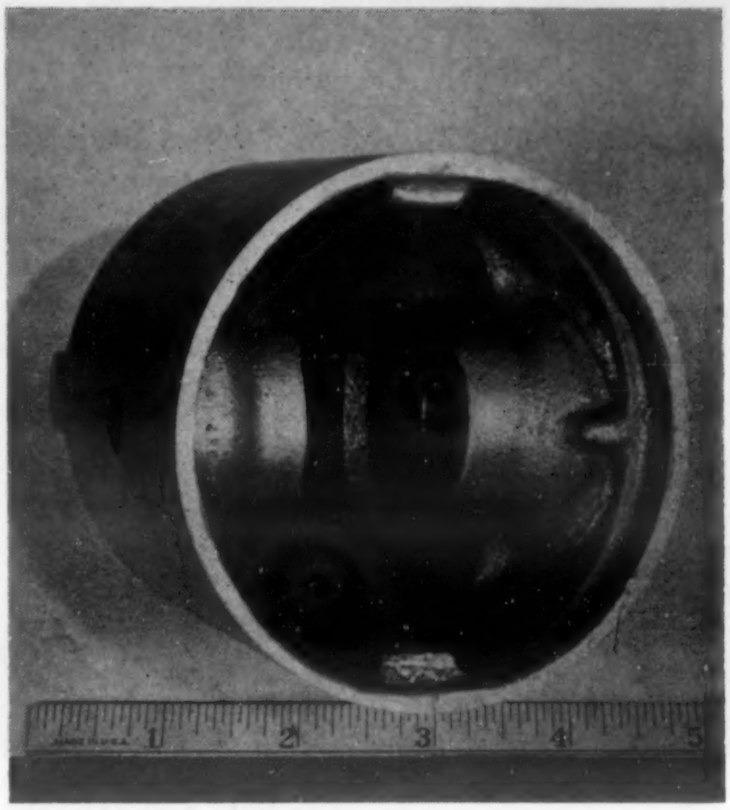


Fig. 4. This magnesium alloy motorcycle piston has a cast-in steel strut.

The cerium loss on holding for 2 hr. is in most cases between 0 and 5%, but did go as high as 12.5% in one instance. The cerium loss on remelting varies from 0.7 to 8.0%.

A comparison of these figures with the corresponding figures in Tables III and IV will readily illustrate the striking superiority of the 220 flux over the two fluxes containing $MgCl_2$.

The only figure that does not seem to be affected by the $MgCl_2$ content of the flux is the alloying efficiency. From this we conclude that $MgCl_2$ containing fluxes can be used for alloying and pouring immediately without serious loss of cerium from the melt.

One difficulty with the magnesium-cerium alloys has been that the castings tend to retain flux inclusions. This is especially true when 220 flux is used, which remains quite fluid and is difficult to skim while pouring. The presence of flux in these alloys was determined by exposing as-cast and machined panels in the humidity room for 24 hr.

To some of the melts which had been made with 220 flux for protection either calcium fluoride (CaF_2) or magnesia (MgO) was added in an effort to thicken and make the flux easier to skim. Panels that were poured immediately after treating the melt with CaF_2 or MgO showed numerous flux spots after exposure in the humidity room.

However, when the melts were held for fifteen minutes after the addition of CaF_2 or MgO the flux spots were markedly reduced as shown by the humidity room test.

It is common practice to use steel screens in the downgates or runners when casting magnesium alloys. Melts were made using 220 flux for melting and alloying with no addition to thicken the flux, 220 flux with 310 flux added, and 220 flux with CaF_2 added. All melts were cast into molds in which the metal was passed through two sets of screens in series instead of the usual one, and were poured immediately after reaching the pouring temperature. These panels had practically no flux inclusions after exposure in the humidity room.

The double screening arrangement may prove impractical in commercial castings. However, it was found that flux free castings could be obtained without serious loss of cerium from the melt, using 310 flux, if the metal was alloyed and poured immediately. Also if scrap is melted using 220 flux and then 310 flux is added and held for 15 to 30 min. before pouring, no trouble from flux inclusions will result.

Recommended Method for Alloying and Pouring

As indicated above, in alloying and pouring magnesium-cerium alloys there are two major problems which are not readily reconcilable: (1) The reaction of the cerium with $MgCl_2$ in the flux and consequent loss of cerium and (2) flux inclusions in the castings

which are more likely to occur with the more fluid non-$MgCl_2$ flux. For these reasons the procedure should be modified depending upon whether the metal is to be alloyed and poured immediately or whether it is to be held after alloying for periods of one hour or more.

A. Alloying and Pouring Immediately:

In this case 310 flux can be used without excessive loss of cerium or danger of flux inclusions. The actual alloying of cerium or Mischmetal is quite straightforward. "M" alloy ingot (Mg-1.5-2.0% Mn) or cell magnesium can be melted depending on whether a magnesium-cerium-manganese or a magnesium-cerium alloy is desired. If "M" alloy ingot is not available, manganese will have to be added to the molten magnesium. This is usually done by the addition of Dow 320 flux containing about 76% $MnCl_2$ of which 44% is manganese.

After the 320 flux is added and stirred into the molten magnesium, a large amount of flux containing $MgCl_2$ will be left in the crucible. This should be removed before the addition of the cerium either by pigging and remelting the metal or by thoroughly sludging and skimming the crucible.

The cerium (Mischmetal) is then weighed and a convenient part of the whole addition is placed in a ladle. The metal temperature should be about 1350 F. The ladle containing the cerium is dipped below the surface of the molten metal and washed around until the cerium dissolves. This is repeated until the total addition has been made. The melt is then thoroughly stirred and brought to the pouring temperature which should be as low as possible and preferably below 1450 F. The molten metal is then held for about 15 min. to allow the flux to separate after which all the remaining flux is skimmed from the surface of the metal. Sulfur or Dow 181 agent can be used to prevent burning during pouring.

B. Alloying and Holding, or Remelting Scrap:

To prevent excessive loss of cerium while holding molten for one hour or more, or in remelting scrap, Dow 220 flux containing no $MgCl_2$ is recommended. To minimize the possibility of flux in the castings, certain practices must be followed.

After the holding period or after the scrap has been remelted using 220 flux, the metal should be prepared for pouring by skimming off all the remaining flux as well as possible, and then either 310 flux or CaF_2 should be sprinkled on the surface. This is done to thicken or inspissate the flux. The melt should be let stand for 15 to 30 min. and then all the remaining flux skimmed off. Sulfur or 181 agent can be used to prevent burning during pouring.

Gating and Risering

The gating and risering of castings to be made from the magnesium-cerium alloys requires some special attention due to certain characteristics of the molten alloys. It is desirable to pour the castings at as low a temperature as possible, both to minimize cerium losses and to obtain finer grain size. To pour at a low temperature (about 1350 F) it is necessary to fill the casting cavity quite rapidly. One method of obtaining this result is by means of slot gates as shown in Fig. 3. Note the inverted position of the piston with the slot gates nearest the wrist pin bosses. This arrangement will give sound castings both in the wrist pin sections and in the head of the piston. It is important that the risers be kept as close as possible to the casting to insure rapid filling and adequate feeding. If other gating methods must be used, the desirability of rapid filling and low pouring temperature should be kept in mind.

The foregoing discussion has illustrated the increasing interest in magnesium-cerium alloys over the past 30 years. At the present time these alloys are superior to any other existing magnesium alloy at temperatures above 300 F, and exhibit properties which compare favorably with aluminum base alloys at 500 to 600 F.

Magnesium-cerium alloys have been used on German aircraft engines, and forged and sand cast pistons have been made in this country. The latter have been tested under actual service conditions with favorable results. It is now possible to use the magnesium-cerium alloys in high temperature applications which were formerly prohibitive for magnesium alloys and effect a considerable saving in weight and also obtain the advantage of decreased inertia in moving parts.

Magnesium-cerium alloys can be handled successfully in the foundry if the following precautions are observed:

1. Clean, flux free castings can be obtained by using $MgCl_2$ containing fluxes, if the melt is to be poured immediately after alloying.
2. $MgCl_2$ free flux (Dow 220) is recommended for all holding and remelting operations in order to keep cerium loss at a minimum.
3. Holding and pouring temperatures should be kept at a minimum.
4. The gating and risering method illustrated in Fig. 3 has been found to give the most satisfactory results. The slot gates should be kept as close to the casting as possible to provide for rapid filling and adequate feeding.

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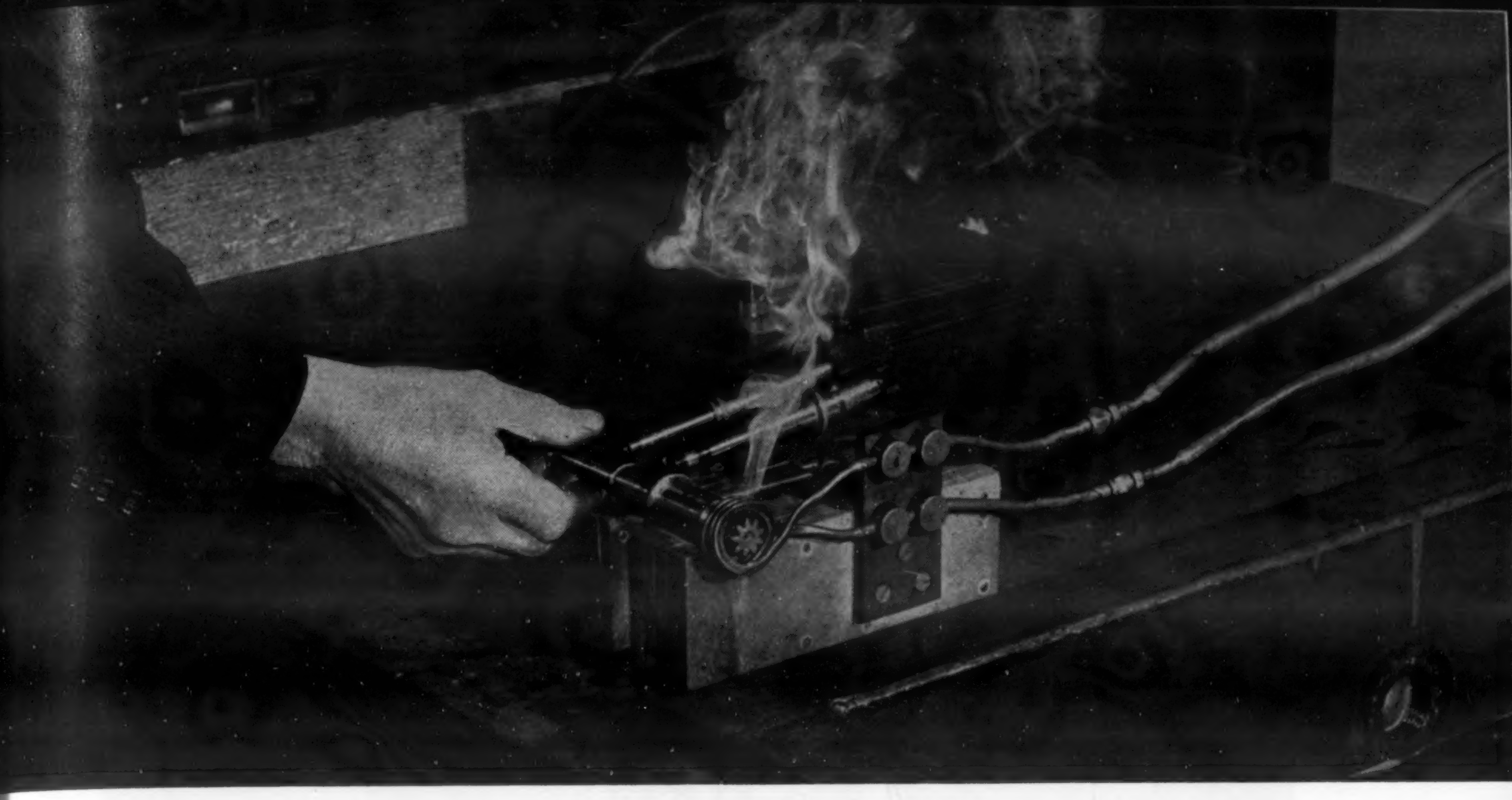


Induction hardening the spline end of a drive shaft.

Induction Hardening of Precision Steel Parts

by WILLIAM BOYLE

THE USE OF HIGH FREQUENCY induction heating equipment, specially designed induction heating coils, automatic timing devices, and specially developed automatic quenching machines has brought about new concepts in the art of heat treating, which in turn have influenced engineering design of precision aircraft accessories during the past four years at one aircraft accessories plant.

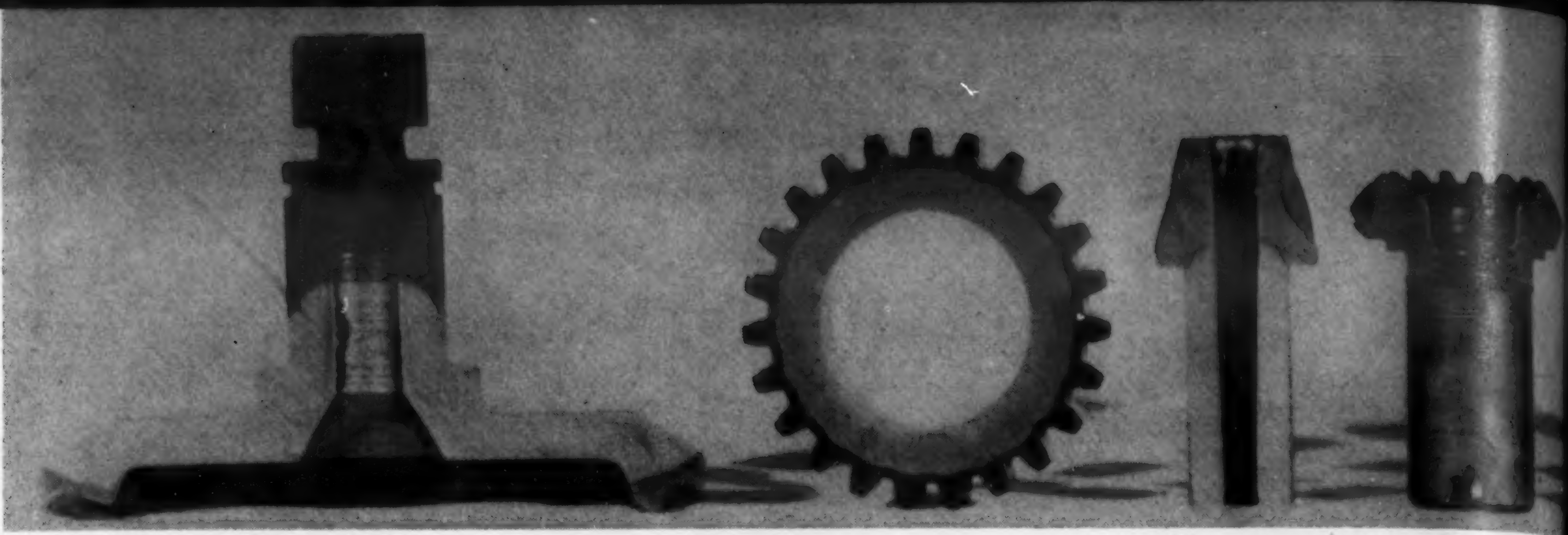
Parts, which in the past were necessarily either case hardened or heat treated by some slow, difficult and costly method, are now being produced in volume production at a great saving in time and cost, using high frequency induction heating.

Surface hardening using high frequency induction heating has been found to be an ideal solution to the problem of retaining the desired internal toughness and a hard surface. This is accomplished by heat treating, prior to induction hardening, to establish a specified core hardness, finish machining to close tolerances, and surface hardening to a specified depth. Due to the short time involved, a few seconds, no appreciable amount of distortion or scaling is evident after induction hardening.

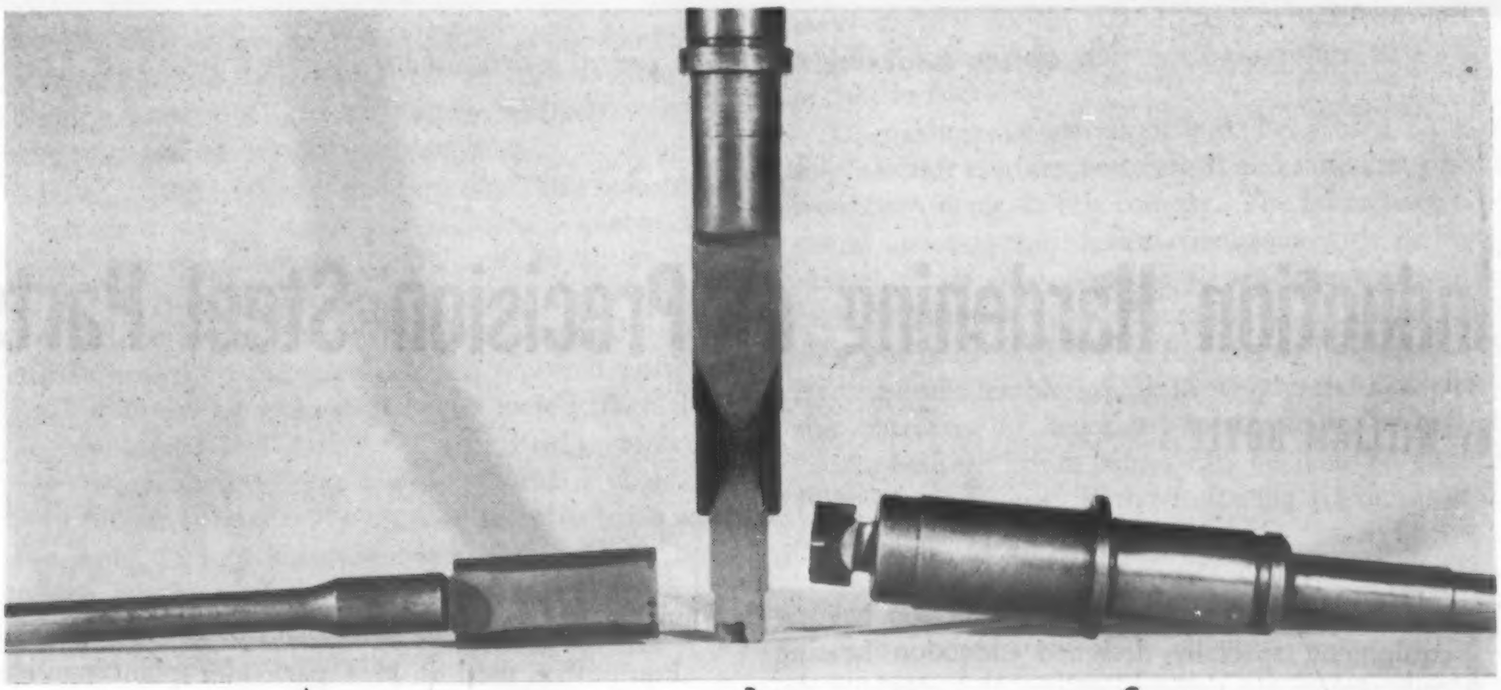
Equipment

Equipment used in this particular plant consists of three spark gap units—one 15 kw. and two 30 kw. high frequency oscillators. The spark gap oscillator consists essentially of a step-up transformer that has a spark gap connected across its secondary winding, and in parallel with this spark gap a capacitance and inductance in series; the inductance of the induction heating device is usually supplied from this cir-

Special work holding and quenching fixtures, plus automatic timing, result in volume production at reduced cost.



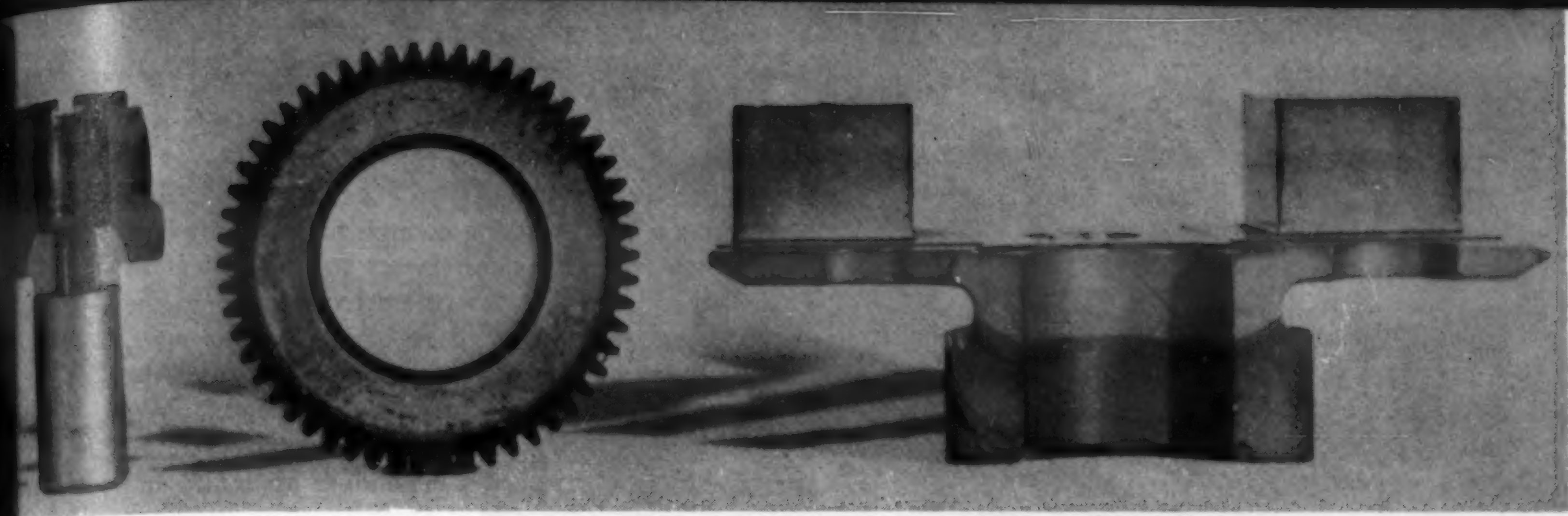
These cross-sectional macro photographs are of actual production parts made of highly alloyed steels. Parts are hardened and drawn to specified hardness, finish machined and induction hardened to the depth of hardening shown by the dark areas. A *is a typical example of through hardening, by means of a specially designed hairpin coil used in conjunction with an automatic quenching machine. Heat treating cycle for this spiral bevel gear includes an induction heating period of low power input long enough to through harden the pinion gear and shaft, and a cycle of a few seconds using high power input for the spiral bevel gear. Induction heating cycles for parts* B *to* G *average only a few seconds.*



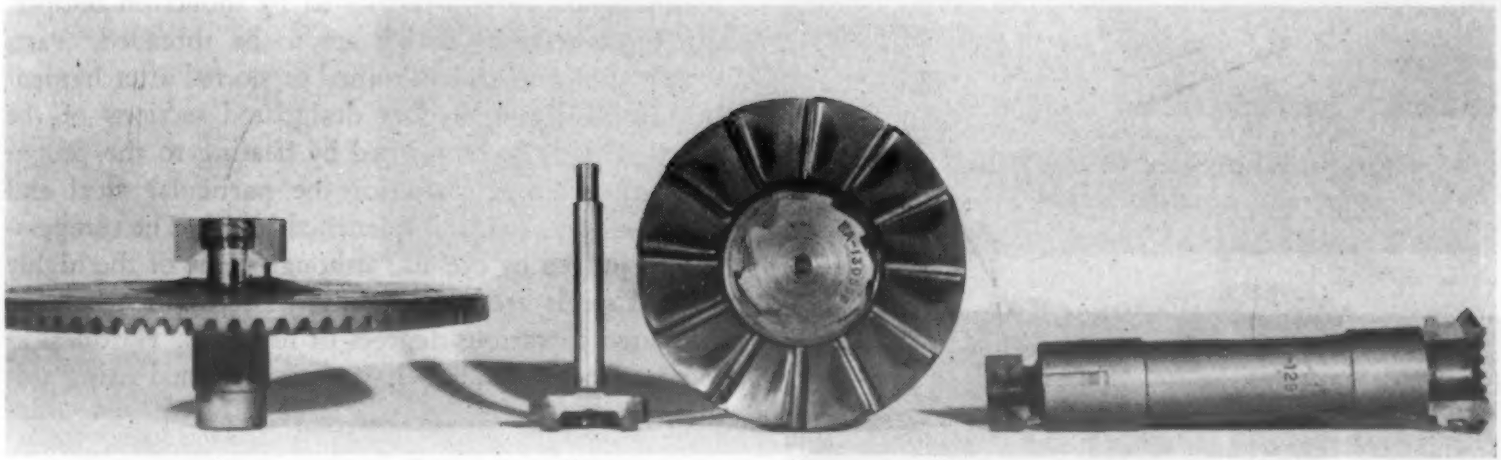
These are typical examples of hend rotated and quenched parts. Drive shaft A *was heated for a short period on the spline end and quenched by hand. Heavy spline shaft* B *has a longer heating cycle. The pinion of armature shaft* C *is induction heated for a few seconds and quenched in the usual manner.*

cuit by means of capacitive coupling. These particular units are equipped with water and air cooled gaps to speed up the de-ionization of the gap. The potential across the high voltage winding of the transformer is usually several thousand volts and each time the gap breaks down the condensers discharge through the inductance coil producing a train of damped oscillations of high frequency. Spark gap oscillators have a frequency of from 20 to several hundred kilocycles. Frequencies selected for our specific purposes run from 100 to 300 kc.

In the surface hardening of bevel and spiral bevel gears and pinions, tooth dimensions must be held to the finished back lash and bearing values. This is accomplished by the proper design of coils, coupling factors, and of major importance, the selection of the proper frequency, power input and heating cycle. Gears and pinions of this type are induction hardened using specially developed automatic quenching machines. The parts are automatically rotated within the coil while heating to assure a uniform distribution of heat. The entire operation is performed by pushing one button controlling an automatic timing device which starts the induction heating equipment and a

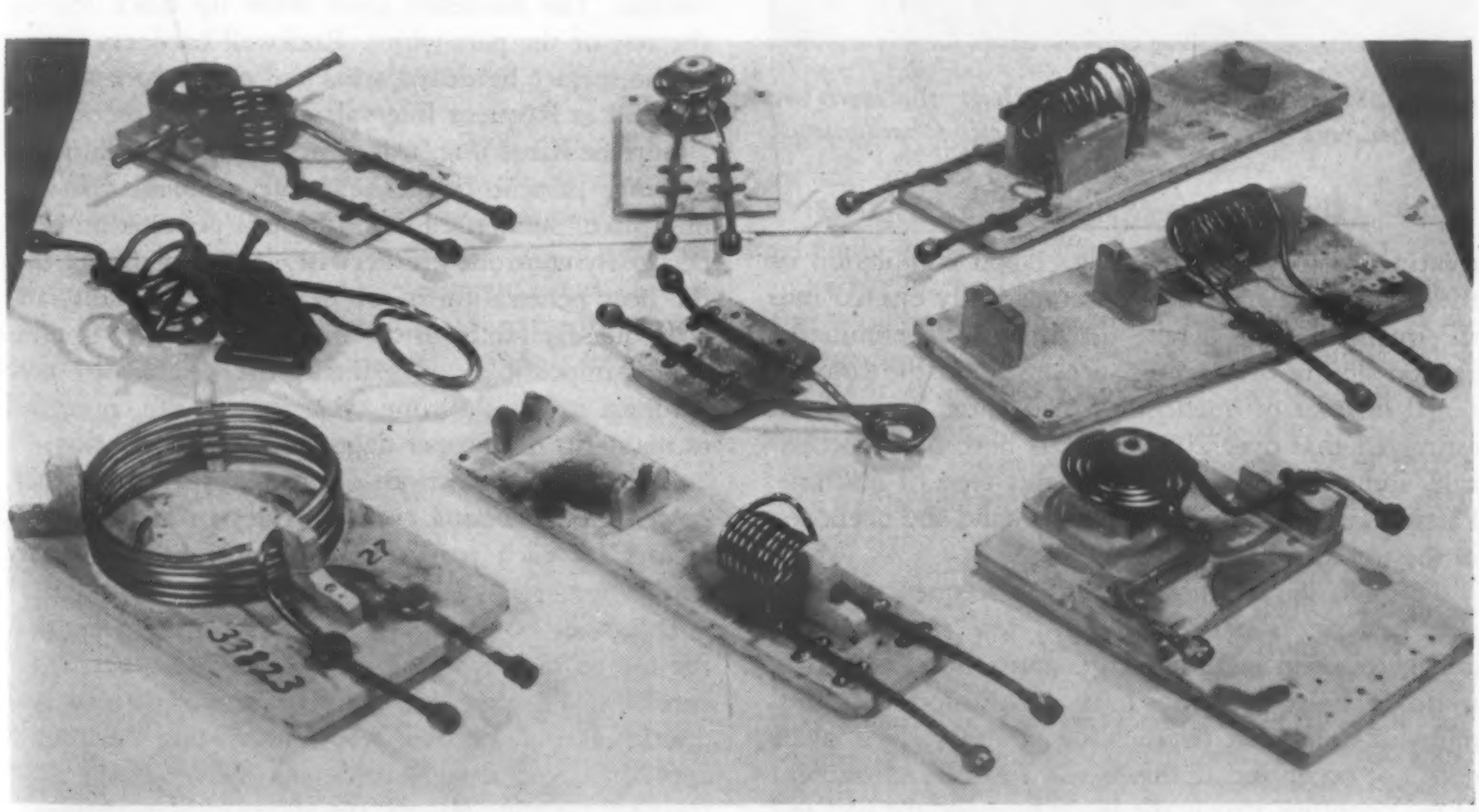


E F G



A B C D

In this photo, A is a crown gear induction heated for a few seconds and quenched by hand; B was hardened with automatic quenching using a very short cycle; C is a starter jaw induction hardened using a pancake type coil. Heat treating cycle for this part consisted of high power input and a few seconds heating time. It was rotated by hand and quenched in the usual manner. Drive shaft D was induction hardened on both the spiral gear and spur to depths shown. The part is quenched automatically.



A few typical coils of special design used on a variety of parts.

The operator is rotating by hand a crown gear during the induction hardening process.

Induction hardening an armature shaft; the teeth are finished and shaved prior to induction hardening.

rotating motor simultaneously. Upon completion of the heating cycle, parts are automatically ejected into the quenching oil. These machines have eliminated any possibility of the human element in the conventional manner of quenching small parts. It has been estimated that over 200,000 parts have been successfully induction hardened using this type of machine. Parts of large design are rotated by hand and quenched in the usual manner.

Through hardening, using high frequency induction heating, is performed on a few specific parts, and here again certain factors must be closely controlled. The power input must be adjusted to a minimum in order that overheating of the surface layers does not occur and if this is not feasible, adjustment of the coupling, that is the space between the coil and the work, will in most cases solve the problem. The heating cycle must be long enough to allow the heat to progress from the outer layers to the center. In this manner, as each layer of steel comes up to the critical point, the increased resistance of this layer, which is proportional to the temperature, causes the heating effect to shift to the layers beneath. Parts hardened in this manner require a time cycle of approximately 10 to 60 sec. depending upon size and design of parts.

The use of induction heating makes possible the tempering of a great variety of parts. Thread cutting operations, where rigid standards require a high hardness, are greatly facilitated by induction tempering those sections which are to be threaded. Parts which are to be drilled, milled or slotted after hardening are also tempered at designated sections of the parts. This is accomplished by heating to the proper tempering temperature for the particular steel and hardness required, and quenched in oil. The temperature is judged by eye and although some of the highly alloyed steels are quite tricky, most of them can be tempered to various degrees of hardness. Hardness as low as Rockwell 20 C have been attained using this method.

Spot Checking Frequent

The importance of the established core hardness and the control of the depth of penetration in the surface hardening of these highly stressed aviation parts has brought about a system of spot checking during the induction heating operation. Operators have been trained to check parts at frequent intervals, by using a specially developed etching technique which shows very clearly the depth of hardness penetration. The hardened areas show up black leaving the rest of the part white. Rockwell hardness testing of the surface hardened areas and of the core are also checked at frequent intervals as an added precaution.

Surface hardening, using high frequency induction heating, presents some practical problems. In the first place, the desired depth of heat penetration must be closely controlled; otherwise, it will be found that the heat penetration is too deep or too shallow, and is frequently far from uniform. Secondly, it is practically impossible to maintain the established core hardness unless the time cycle is carefully controlled to maintain the proper depth of heat penetration.

Briefly, the selection of the proper frequency, power input, heating cycle, coil design and coupling factors for each particular part must be thoroughly engineered.

It cannot be stressed too strongly, however, that the use of high frequency induction heating is not a cure-all. We have learned that the intelligent and discriminating use of the equipment and the proper application of design has made possible the heat treating to any desired specifications by induction heating.

According to German experience, almost complete precipitation hardening is obtained after only 2 min. (Photo courtesy: Reynolds Metals Co.)

German Practice in Solution Heat Treatment of Rolled Aluminum Alloys

Translated by B. M. PEARSON *

THE INDUSTRY OCCUPIED with fabricating the light alloys conducts severe forming work, generally in conjunction with a solution heat treatment, which is repeated before each subsequent forming process. For practical working, heat treatment times chosen often lie considerably above the requirements of the material. In the following, the solution heat treatment times are considered in relation to the condition of the material before such treatment.

* *From an article by W. Lott,* Aluminium, *Berlin, Vol. 25, No. 7/8, pp. 279-282, 1943.*

Deformation stresses in formed aluminum alloy sheet can be removed by a 2-min. solution heat treatment at 932 F.

The German light alloy semi-finishing industry generally delivers aluminum-copper-magnesium sheet and strip in the hardened and roller levelled condition. Solution heat treatment time, necessary to attain required strength values, is ascertained on a sample work-hardened by rolling. For a 1-mm. thick sheet, for example, a time of 15 min. was found necessary, to remove forming stresses and to take a sufficient amount of the constituent Al_2Cu into solution, serving for the age hardening.

In the rolling mills, aluminum alloy sheet and strip undergoes a final reduction of more than 20% to the required thickness. At temperatures from 662 to 725 F, most of these deformation stresses are removed after several hours by recrystallization. At higher annealing temperatures, the process proceeds more rapidly and completely and at 932 F attains practical finality, even before the homogenization reactions are completed.

For aluminum-copper-magnesium alloys, 932 F is

the annealing temperature set by the alloying composition. The time required for the solution heat treatment is also a question of the distribution and size of the Al_2Cu containing crystallites. The minimum annealing time becomes shorter, if by the application of a suitable casting process, localized enrichment (segregation) can be prevented and if a corresponding amount of deformation be practiced, suitable for sufficient breaking down of the constituents, required to pass into solution during the heat treatment.

Further work, subsequently performed on the material, by bending, pressing, deep drawing, stretch forming, etc., will then be done with the material in the following condition:

1. As delivered, hardened and roll straightened.
2. Immediately after quenching from 932 F.
3. After softening heat treatment.

The material may be worked until its capacity for deformation is exhausted. Mechanical strength values obtained are then built up as follows:

A. Alloying strength, soft annealed and roller levelled.
B. A+ strengthening by solution heat treatment.
C. B+ age hardening strengthening.
D. C+ roller straightening (as delivered).
E. D+ strengthening by work hardening, for example, by stretch forming.

The value of the total strength obtained is therefore dependent upon the strength of the semi-finished, rolled material as delivered and the stress-free, cold hardening applied.

Heat treatment at 932 F, in addition to removing the deformation stresses, removes age hardening strength, and the material is in the most favorable condition for working. As any separation of Al_2Cu from the mixed crystals is prevented by quenching, strength values in the age hardened condition are again obtained as an optimum value after storage.

Stresses Removed Quickly

Deformation stresses are removed at 932 F in a very short time. Inasmuch as the material has been subjected to considerable deformation, removal of the stresses is effected by recrystallization; with smaller amounts of deformation, by crystalline relaxation. In the first case there is formed a completely new, stress-free structure and in the second case, the softening is effected without any structural conversion and certain residual stresses are still retained. The recrystallization proceeds quickly. The same holds true for crystal relaxation as can be demonstrated in the following manner.

A sample of the material, 1.5-mm. thick, was given a 10% elongation in a tensile test machine, immediately after quenching from 932 F. Then one series was subjected to a solution heat treatment in a salt bath for 2-min. periods. The second series was given the same treatment for 20 min. The practical conditions thus involved were 10% elongation and heat treatment repeated 5 times. Strength values were ascertained after cold age-hardening for 72 hr. It was found that with the degree of elongation given, after a solution heat treatment of 2 min., a considerable amount of stresses not capable of being removed by recrystallization remain. These, however, cannot be removed to any greater degree up to the commercially interesting heat treatment times of 20 min. The full hardening value obtained, as nothing has been taken into solution, again attains the same value, independent of the annealing time.

If the material in the as-delivered condition is subjected to a solution heat treatment before working, this treatment is done to remove the cold age hardening effect. This is achieved at the precise moment that the material reaches the temperature of 932 F. In the case of 1.0-mm. thick samples, it was shown that when tested immediately after quenching, after 1 sec. in the salt bath, the same strength values were recorded as with samples that had been annealed for a period as long as 60 min. The strength values of the age hardened condition were also here—independent of the heat treatment time—again attained to the full extent.

Up to now, the question discussed has been the working of rolled, semi-finished products, in the homogenous condition, given by a solution heat treatment. In order to maintain a relatively soft condition in the material over a longer period of time, i.e., to suppress spontaneous hardening, the soft annealing or segregation heat treatment is practiced. At temperatures from 662 to 725 F the separation of Al_2Cu from the mixed crystals is intended. The solution heat treatment follows after deformation for the purpose of increasing mechanical strength by precipitation hardening. There is thus obtained a removal of the deformation stresses, with simultaneous taking into solution of Al_2Cu. The heat treatment time necessary for this can be determined in the following manner:

Sheet of 1.0-mm. thickness, in the as-delivered rolled condition, is given a heat treatment at 689 F for 1 hr. and given a 10% reduction by cold rolling. After heat treatment and cold rolling has been repeated three times, the taking into solution again of the constituents effecting the age hardening can be achieved by heat treatment times varying from 25 to 60 min. at 932 F.

Precipitation Hardening in 2 Min.

It was shown, by testing in this manner, that practically complete precipitation hardening was obtained after only 2-min. heat treatment time. The only practical effect achieved by prolongation of the heat treatment time up to 60 min. was an insignificant gain in the yield point.

In this connection, it should be remarked that only the first solution heat treatment—in the rolling mill—requires a longer heat treatment period, as from the cast material, primary and relatively coarse crystallite separations have to be passed into solution. From the solid solution, the subsequent separations occur in a dispersed form. Consequently, taking back into solution, of such a dispersed separation, requires appreciably shorter times. From the above, it may be stated that for an age hardening aluminum alloy, at individual heat treatments at 932 F, there is no sound reason why a heat treatment time of longer than 2 min. should be necessary. With this fact having been definitely confirmed by detailed investigation, further investigation was then undertaken with the object of studying elongation, drawing and deep drawing behavior in the light of the above facts.

In order to avoid any untoward occurrences when changing over under practical working conditions to these shorter annealing times, it should be pointed out that the annealing time of 2 min. was chosen to confirm the belief that as opposed to the more frequently employed times of 20 min., considerable economies in operating time would be possible under practical conditions. In measuring the actual times necessary, the heat treatment furnace layout, the charging arrangements and the thickness of the sheet being handled of course enter into consideration.

In a salt bath furnace, usually, the heat treatment temperature is spontaneously attained. Consequently, no errors are encountered if the soaking period is assumed to be the same as the immersion period. A necessary condition for this assumption, however, is that the liquid heat carrier in the bath can contact the surface of the material being given the heat treatment, without hindrance. The annealing times given in test must be regarded as being concerned exclusively with the heat treatment of individual parts in a salt bath furnace. The shortened time of soaking obviously also can be applied to heat treatment in forced air circulation furnaces. The holding or soaking period can nevertheless only be calculated from time viewpoint where the part being heat treated has attained the temperature required in all locations.

Charging Arrangement Important

Careful attention must be paid to the charging arrangements for the heat treatment basket. Even in the salt bath, the part is subjected to a delayed heating effect if individual parts are placed too close to each other. In forced air circulation furnaces, the furnace should be so designed that air blocks and consequent turbulences are avoided. Air blocks cause uncontrollable delays in the heating and as a result localized low temperature effects will result. Temperature balance in the part can only be obtained by prolonging the heat treatment time.

A 5-min. heat treatment time (soaking period) for sheets of from 0.3 to 1.2 mm. thickness, according to available experience, should be entirely ample. For sheet thickness of 1.5 to 3 mm. a heat treatment time of about 10 min. is recommended.

The shortening of the annealing time is not only desirable for the purpose of increasing the annealing capacity and shortening the finishing time; it is a practical requirement imposed when clad sheet is being fabricated. As is known, aluminum-copper-magesium alloys, because of their relatively small corrosion resistance, are clad with pure aluminum or with copper-free aluminum alloys respectively. The value of the clad layer is strongly reduced, if the copper is allowed to diffuse from the base metal into the surface sheet. This diffusion is a function dependent upon the time factor and can be suppressed by the choice of suitable cladding alloys. Mills rolling this class of material try to use cladding metals with an enhanced resistance to copper diffusion and even tolerate certain production difficulties to achieve this aim. The fundamental requirement, nevertheless, which is to conduct the heat treatment process for a period no longer than is necessary, remains as before with due consideration to the corrosion behavior. For a 1-mm. thick sheet a total heat treatment time of 60 min. is sufficient to allow the copper to penetrate to the upper surface. If one now considers that during the rolling process a heat treatment of about 15-min. duration has already been given, then for the fabricator of the clad sheet, for solution heat treatment, there only remains a total time of less than 45 min. As in many operations, 1-mm. thick sheet is heat treated for a length of 20 min. After the second solution heat treatment, the corrosion resistance value of the clad sheet is very markedly reduced. Previous practice was to protect the clad surface with an additional finishing coating. Today, for reasons of weight and raw material economy, it is necessary to eliminate additional finish for corrosion protection, and the clad metal is required in itself to resist corrosion. These increased requirements on the part of the raw material can, however, be fulfilled even after a forming treatment providing that a correct heat treatment as outlined above is given during fabrication.

In conclusion it may be said that in the aluminum alloy sheet fabricating industry the heat treatment time given for hardening aluminum-copper-magnesium alloys can be appreciably shortened. Removal of work stresses is effected within 2 min. The hardening effect spontaneously disappears and a solution heat treatment after previous segregation of the material subjected to age hardening is likewise completed within 2 min. It has been pointed out that the heat treatment time that should be given is dependent upon the characteristics of the heat treatment plant available.

New Age-Hardening Stainless Steel Provides

by T. C. DU MOND, *Managing Editor*, MATERIALS & METHODS

Stainless "W" meets need for steel which has strength hardness and corrosion resistance and which can be fabricated by all ordinary methods.

PERSISTENT RUMORS during the latter years of the war became fact early this year with announcement of a new precipitation hardening stainless steel of the 18:8 type. This new steel, developed and produced by Carnegie-Illinois Steel Corp., United States Steel Corp. subsidiary, is known as Stainless "W." Because of its ability to be heat treated, stainless "W" combines the strength and corrosion resistance of 18:8 steels with the hardness required for many applications. This steel was developed a few years ago and immediately placed on the Army Air Force secrecy list.

Stainless "W" is expected to attain greatest use in bar form, but it can be produced in any cast or wrought form including strip, sheet, wire and tubing. Unlike most other types of 18:8 stainless steel, stainless "W" is strongly magnetic.

Results of 100-hr. immersion tests in boiling copper sulfate—sulfuric acid solution, evaluated by bend tests and microscopic examination, show that this steel is not susceptible to intergranular corrosion.

War experience with Stainless "W" indicates that it can be treated successfully in standard equipment, that no difficulty is encountered through warping or dimensional changes during the heat treating operations. Fabrication is relatively easy, and high joint efficiencies can be achieved through spot, metallic arc, atomic hydrogen and helium-arc welding, particularly when solution annealing, followed by aging, is used as a post-welding treatment.

Ordinarily, in the annealed condition, Stainless "W" has a hardness of 22 to 28 Rockwell C; a tensile strength of 120,000 to 150,000 p.s.i., and a yield strength of 75,000 to 115,000 p.s.i. By proper heat treatment hardness can be raised to 39 to 47 Rockwell C; tensile strength to 195,000 to 225,000 p.s.i. and yield strength 180,000 to 210,000 p.s.i.

In this new steel, the basic composition is so balanced as to insure, without the necessity of cold working, the almost complete austenite-to-ferrite (martensite) transformation and the subsequent precipitation hardening. A typical analysis of Stainless "W" follows:

Carbon	0.07 %
Manganese	0.50
Phosphorus	0.010
Sulfur	0.010
Silicon	0.050
Nickel	7.00
Chromium	17.00
Titanium	0.70
Aluminum	0.20
Iron	balance

Titanium is the most important single element as it serves a double purpose. First, it is the primary precipitation hardening element and, second, it is a strong ferrite former. When other elements are properly balanced, the optimum percentage of titanium has been determined as being in the range from 0.40 to 1.00%. Aluminum is added to the mixture to serve primarily as a deoxidizer. Any excess of aluminum that remains in solid solution serves to work with the titanium in making the steel precipitation hardening.

Carbon Acts as Control

Carbon does not serve directly in producing the precipitation hardening reaction, as do titanium and aluminum, but it does act as a control on the amount of soluble titanium that will be available for the reaction. The behavior of nitrogen is much the same as carbon, for it combines with, thereby immobilizing,

Strength Without Cold Working

the titanium. Nitrogen also stabilizes the austenite and therefore must be controlled and held as low as possible (to residual amounts).

Nickel, manganese, chromium and silicon, the remaining alloying elements in the composition, serve to control the austenite to ferrite balance. Nickel and manganese are austenite formers while chromium and silicon are ferrite formers. Research has indicated that these elements, possibly excepting nickel, have little or no effect in producing the precipitation hardening reaction.

Columbium can be successfully substituted for titanium to produce precipitation hardening.

Solution annealing of Stainless "W" causes the precipitation hardening constituents to go into solid solution in austenite. Upon cooling to room temperature the austenite transforms into ferrite which is then supersaturated with the precipitation hardening constituent. Aging consists of reheating, after the austenite transformation has been completed, to a temperature which will cause the precipitation hardening constituents to precipitate out of the supersaturated ferrite and impart the desired change of properties.

Solution Annealing at 1200 F

The temperature range for solution annealing Stainless "W" begins at about 1200 F, which is 100 to 200 F above the temperature at which the material begins to transform to austenite and extends to approximately 2000 F. As the solution annealing temperature rises, hardness and yield strength of the material increases slightly and passes its peak at between 1700 and 2000 F, while the corresponding tensile strength simultaneously reaches a minimum value at about 1600 F and then increases slightly with increasing temperature.

The minimum holding time is generally short. On thin sections 5 min. at temperatures in the higher range (1850 to 1950 F) has been found to be satisfactory. On heavier sections, where it is more difficult to determine when the material has reached temperature, slightly longer soaking times are recommended. Stainless "W" can be hardened uniformly throughout unusually heavy sections without difficulties normally attendant upon quenching and surface hardening.

The desired combination of qualities determines which of three specific temperatures between 500 to 1050 F shall be used for precipitation hardening (aging). Lowest ductility with maximum tensile and yield strengths are obtained at 950 F; improved ductility with slightly lower tensile and yield strengths result from a temperature of 1000 F. If aging is done at 1050 F ductility is improved even more, due to the formation of some austenite, but with further sacrifice of tensile and yield strengths.

Can Be Annealed Often

Although Stainless "W" is stiff to work, it can be subjected to drawing operations and given intermediate anneals as often as desired in the course of deep drawing and then heat treated to develop the desired high physical properties in the whole piece. Shop tests indicate that machinability of this new material is slightly better than that of austenitic 18:8 stainless steel.

Many applications are foreseen for this new steel particularly in bar form. Preliminary commercial applications indicate its usefulness where hardness, plus corrosion resistance, is essential. Such applications include cams and rollers in food handling and bottling equipment; bearing and valve parts subjected to service in the oil, chemical and food industries. Other applications, involving high strength alone, or in combination with hardness and corrosion resistance, can be filled successfully with Stainless "W."

Stainless "W" can be rolled into billets, bars, sheets or shapes, drawn into wire or pierced for tubing, or it can be forged to nearly any shape or size. In any form, the finished product is amendable to heat treatment to develop desired hardness and will have corrosion resistance superior to that of heat-treatable straight chromium steels and approximately the same as that of 18:8 stainless steel in most corrosive mediums.

Reasons why tools dulled on runs with well-tried set-ups are determined by tests which show alloy variations.

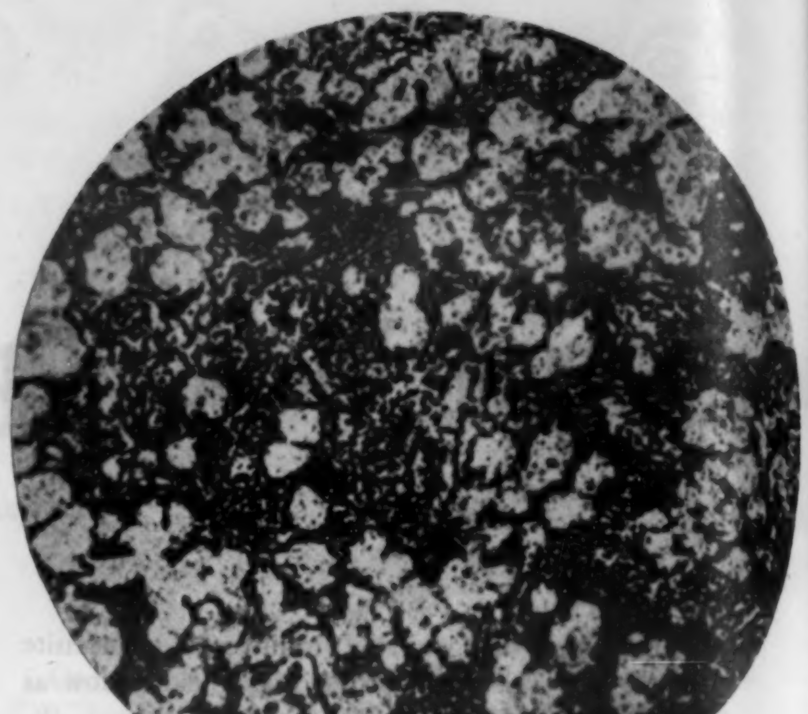


Fig. 1. This photomicrograph (magnification 250X) is the typical normal structure of aluminum die casting alloy, SAE-305.

Metallographic Examination Discloses Causes of Ma

by N. R. CUSWORTH, J. W. CAUM AND S. S. KINGSBURY, *formerly with Philadelphia Div., Bendix Aviation Corp.*

NON-FERROUS CASTINGS which appear to be perfectly sound and satisfactory with respect to surface appearance may contain internal defects, of both a gross and minute nature. Defects such as porosity, cold-shuts, cracks and gross segregations can be detected satisfactorily by means of X-ray.

However, there have been several occasions where investigation of machining difficulties by X-ray testing indicated the castings were sound. Further investigation by metallographic study determined the presence of minute defects such as hair-line cracks, certain forms of cold-shut, non-uniform microstructure and segregation of inter-metallic compounds.

Needless to say, the presence of non-metallic inclusions in the form of hard spots in the castings results in considerable machining difficulty, particularly in grinding and tapping operations. While the percentage of defective castings has been of relatively small magnitude, it is true that a few defective castings can cause considerable trouble when mixed in a lot of relatively good castings, since it takes only one bad casting to ruin the tooling or set-up of the job.

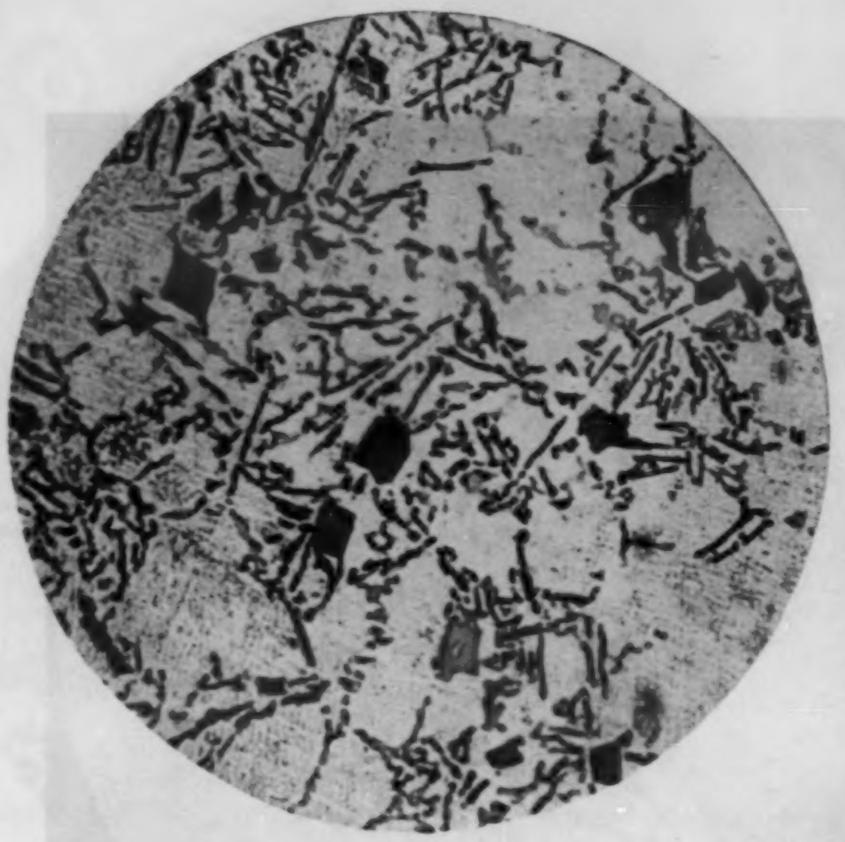
In the making of bezels, cases, frames, connections, covers and many other special forms, SAE-305 aluminum alloy die castings were used. In these applications it was necessary for thin sections to be pressure-tight against air and oil, and, in some cases, to stand heavy stresses in small sections. In practically all instances the metal had to present a clean, smooth surface after various machining operations.

Some of the causes for trouble are shown in accompanying photomicrographs. The etchant in all cases was 0.5% hydrofluoric acid in water.

Rapid Dulling of Tools

In Fig. 1, taken at a magnification of 250X is shown a typical normal structure for the alloy—a modified eutectic brought about by die casting.

During a turning operation on one of the castings, tools were dulled at a terrific rate. By the time two 6-in. dia. castings were turned, the tool had to be replaced. Fig. 2, also at a magnification of 250X, shows



Figs. 2 (left) and 3. A high copper content in the alloy permitted the formation of primary silicon, resulting in rapid tool dulling. The structure is shown (left) at 250X magnification and (right) at 500X magnification.

s of Machining Difficulties

the condition found. In the eutectic matrix are particles of primary silicon, an extremely hard constituent. Analysis of these castings showed them to contain 4% copper, 13% silicon, the remainder of the analysis normal. Evidently the presence of copper changes the composition of the eutectic point to a lower silicon content, permitting the formation of primary silicon. This impression is borne out by Fig. 3 at a magnification of 500X of a casting which has a copper content of 2% and silicon 12.5%, where the same trouble was encountered to a lesser extent.

The extreme of this condition is shown in Fig. 4, magnified 25 diameters, where there are very large primary silicon particles. This material dulled tools very rapidly. Presence of the large particles at the surface resulted in a spotty anodized finish which in turn caused enamel to flake off after painting.

An interesting case of cracks developing during a machining operation is illustrated in Figs. 5 and 6 (magnification 25X). Fig. 5 shows a raw casting at the surface. Noticeable is a line of separation where the metal had not completely fused. It could be called a cold shut at the surface. Fig. 6 shows the same fault in the surface of a casting after machining. The tool caught on the line of separation of the material and ripped it apart.

In turning down some cam housing the machine operators were unable to obtain a satisfactory finish. The same set-up had been satisfactory on another lot of castings. Micro-examination of a cross section of the defective cams near the surface showed the microstructure in Figs. 7 and 8 (magnification 100X). Small gas pockets ranging from 0.002 to 0.005 in. below the surface were revealed on sectioning resulted in uneven cuts. Also to be seen are needles of beta Fe-Al-Si, a hard constituent detrimental to smooth cutting. These were due to the presence of 3% iron, 1% over the maximum for the alloy.

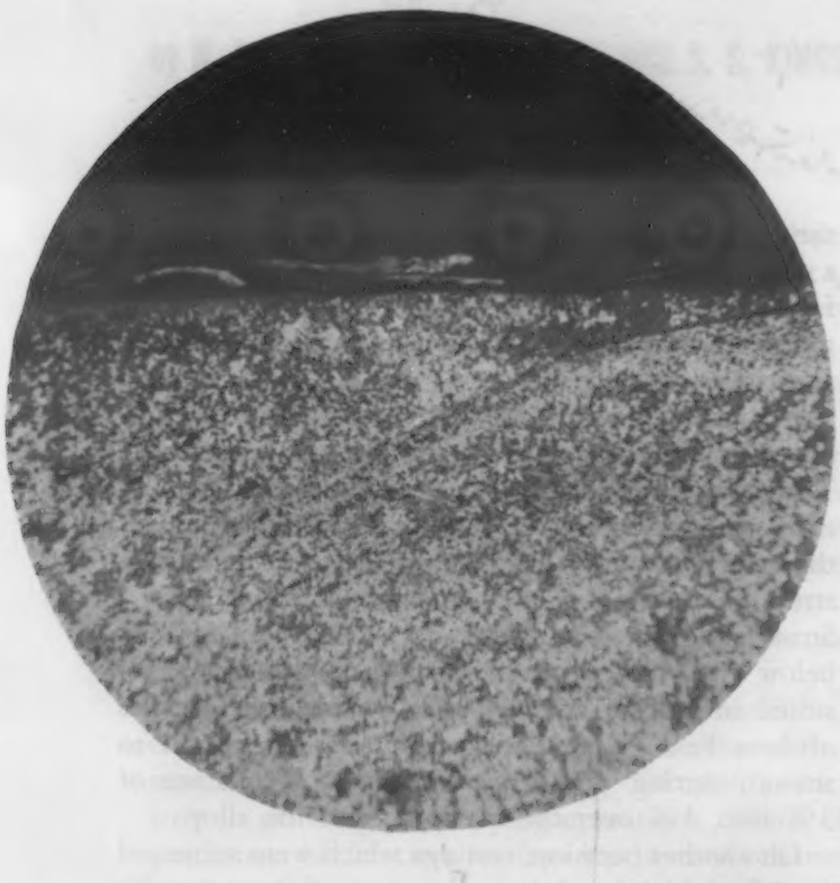
On another occasion, castings which were subjected to a fair amount of stress began to fail on test by cracking after vibration. X-ray did not reveal any defects which would cause the failures. Test bars

Fig. 4. In this 25X magnification the presence of primary silicon is readily apparent.

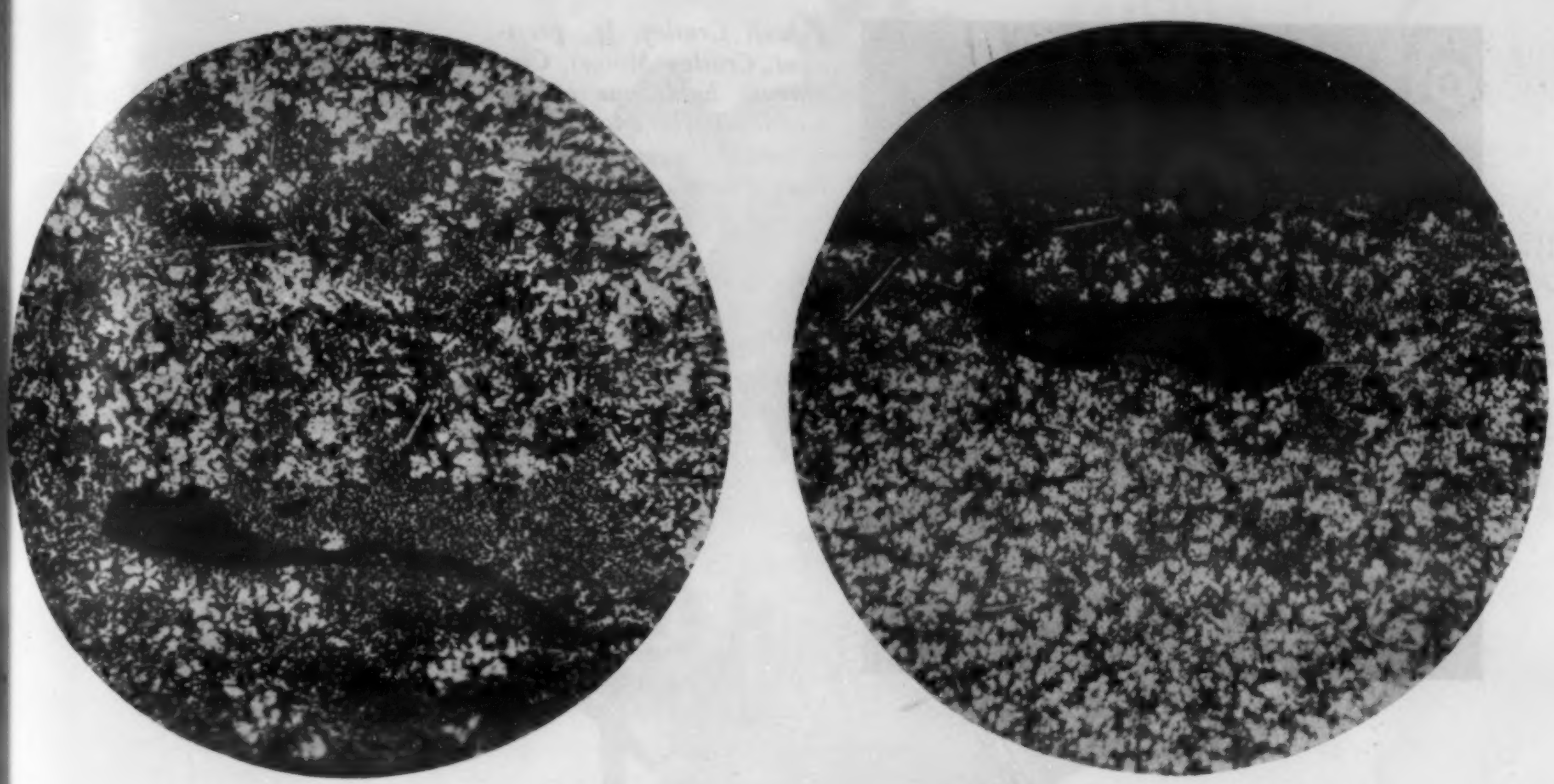
were cut from the castings and tensile tests were made, showing 19,000 p.s.i. where 33,000 p.s.i. minimum was specified. Chemical analysis was normal, so microstructures were prepared. Investigation showed the castings to be full of fine hairline cracks running in all directions.

A subcontractor reported dulling of carbide tools on die castings. Several of the castings sent to the laboratory for a metallurgical analysis were found to be normal, so cross sections of several castings were prepared for metallographic examination. At a magnification of 50X, Fig. 9 reveals conditions of the alloy's surface. Oblong particles of metal with dendritic patterns can be seen. It appeared as though the particles were not fused to a main body of the material, so a 500X magnification photograph was taken to establish the fact, Fig. 10. The line of separation is very clear. Evidently these were small particles of the alloy surrounded by a film of aluminum oxide shot into the mold cavity with the remainder of the molten alloy. Tools hitting these particles tore them out, resulting in a rough cut.

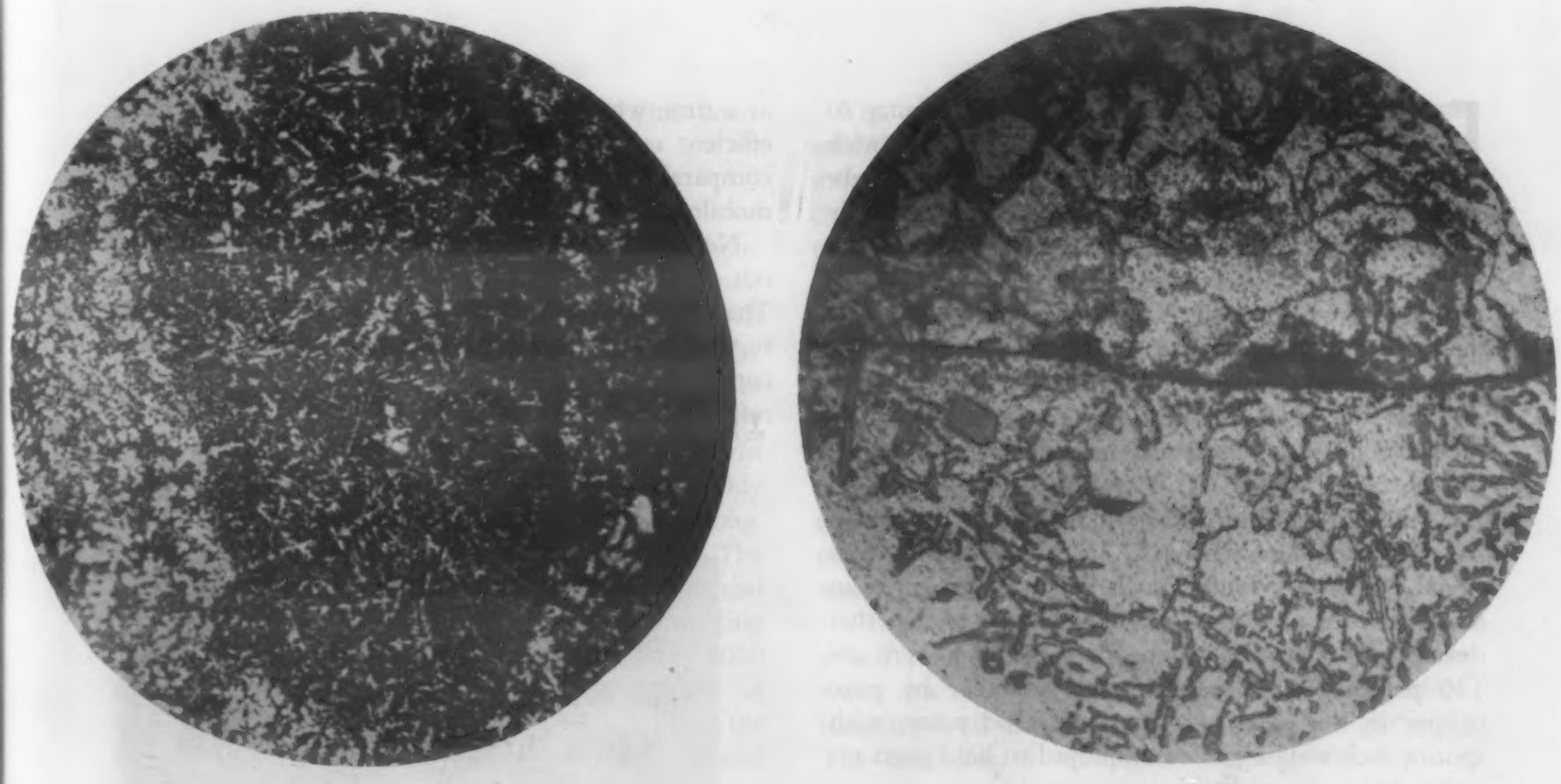
There were many instances of faulty material being reported by employees, which proved groundless after metallurgical investigation. Often the cause was an operator trying to exceed the rate set for the particular job, by changing speeds, depths of cut and cutting angles. So now, every angle of the machining, finishing and inspection is checked before checking the material in the laboratory.



Figs. 5 (left) and 6. The line of separation in Fig. 5 resulted in the tear in Fig. 6 after machining.



Figs. 7 (left) and 8. Too much iron in the alloy resulted in a poor finish, caused by minute gas pockets and ferritic needles. (Magnification 100X)



Figs. 9 (left) and 10. To establish the belief indicated in Fig. 9 that metal particles were not fused to the main body of material, Fig. 10 at 500X magnification was taken to show the condition clearly.

Powell Crosley, Jr., president, Crosley Motors, Cincinnati, holds one of the Crosley-Taylor engines that is hardly bigger or heavier than a standard typewriter.

Brazed Stampings Basis of New Auto Engine

by HAROLD A. KNIGHT, *News Editor,* MATERIALS & METHODS

FOR SEVERAL YEARS there has been a tendency to replace conventional materials and methods with those that are more available or that save weight without loss of strength, or that provide especially needed design flexibility or that are cheaper or faster in production. This is especially true in automotive production where there is a constant attempt to reduce dead weight and thereby increase efficiency.

A new and novel application of different materials and methods is to be found in the new Crosley automobile engine, to power a car which will soon appear on the 1946 market. This engine gets 50 miles to the gallon of gasoline at a 30 m.p.h. speed and which has a top speed of 65 m.p.h. Instead of the conventional cast iron cylinder block and forgings, it is an all-steel stamped copper-hydrogen-brazed engine that develops 26 h.p. and weighs, bare, 58 lb. There are 120 parts in the engine, brazed together by pure copper in the form of wire, strips and paste, with spot or tack welding often employed to hold parts together just prior to brazing.

The main features of the engine are that it has half the normal weight for its 26 h.p.; it utilizes a minimum amount of space and has great compactness; and it relies upon materials that are plentiful at a time when castings are still scarce. It is a most efficient engine package for size and weight and is comparable to an airplane engine rather than an automobile motor.

Neither is this combination of materials and methods confined to automobile engines as its chief outlet. The Navy used this type engine for generator sets, such as on P-T boats. Other likely uses are for air-conditioning on trucks and buses, for compressors, for refrigerator freight cars, for marine engines for small

In a move away from the traditional, an automobile engine cylinder block is given strength and lightness by extensive use of copper brazed steel stampings.

The engine, complete with all accessories, including generator and starter, weighs 138 lb.

boats, for small farm tractors and for golf club lawn mowers.

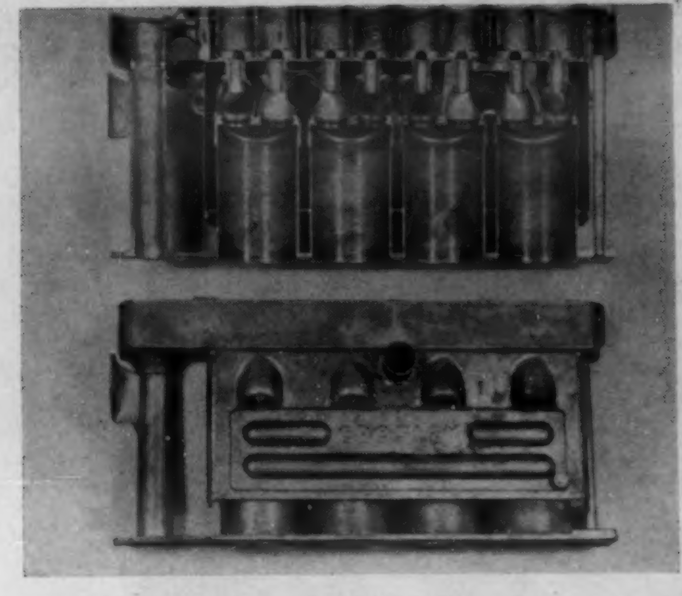
Materials in the Engine

For one 4-cylinder block, stampings number about 120 pieces. Light walled alloy steel tubing is used for the cylinders and cam follower guides while SAE 1010 and 1015 steel stampings are used for the cylinder heads, intake and exhaust ports, valve cases and water jackets. The parts are held in place by shrink fits, spot weld or crimping operations and form a firm structure, even before brazing. The assembly is then copper brazed in a special furnace, 60 ft. long, which handles 28 block assemblies per hr. The furnace has a pre-heat chamber, brazing chamber and cooling chamber. At a certain point in the cooling chamber, where the block has been cooled from 2060 F to about 1500 F, a cool neutral atmosphere of hydrogen and carbon monoxide is introduced into the furnace and allowed to circulate around the brazed assembly, which is thereby quickly cooled to about 1100 F. The speed of this temperature drop determines hardness of the cylinder walls, cam follower guides, and intake and exhaust valve seat inserts, which are made from an alloy steel.

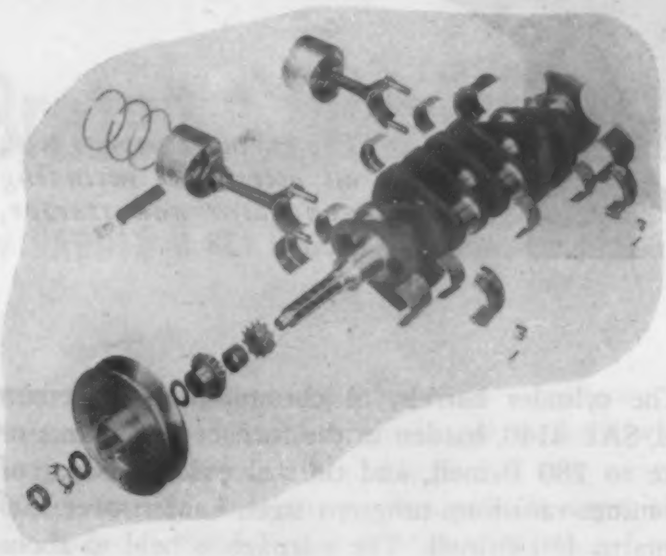
The cylinder barrels, of chromium molybdenum steel, SAE 4140, harden in the furnace 100 points or more to 280 Brinell, and the valve seat inserts, of chromium-vanadium-tungsten steel, harden over 200 points to 450 Brinell. The warpage is held to about 1/64 in. in 16 in. by properly designing the stampings as to the height of extrusions, control of press fits, and rate of pre-heat and cooling in the brazing furnace.

A somewhat unusual material and application is the clear, hard coat of plastic placed on the inside of the water jacket, which, after baking, becomes so durable that it cannot be removed in a stripping tank of a strong caustic or acid solution. The coating stands up under 375 F.

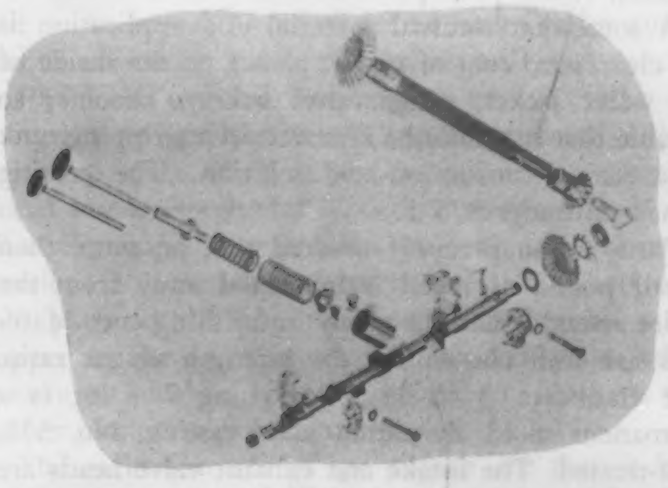
Parts are so precisely tailored that no more than a half pound of metal is machined away from the entire assembly and then only in finishing cuts. Materials are well chosen for the strength-weight ratio. The crankcase, 3 in. high, weighing 7¾ lb., is a permanent mold aluminum alloy casting, No. 355, heat-treated. The intake and exhaust valve heads are of 21:12 chromium-nickel steel, and the stems are of SAE 3140 steel, with flame-hardened tips. Pistons are cast from a heat-treated aluminum alloy. The



The cylinder block is made of light-walled alloy steel tubing for the cylinders and cam follower guides and of sheet metal stampings for the cylinder heads, intake and exhaust ports, valve cases and water jackets, assembled by brazing.



The crankshaft is designed about 1 in. shorter than a conventional 3-bearing shaft, which requires a larger center bearing and an increased shaft length.



A bevel gear drive was preferred to a chain drive for the overhead camshaft because the vertical shaft could be used to carry the lubricating oil under pressure to the five camshaft bearings.

skirts are cam ground and anodized after final machining. The piston pins are of the floating type with aluminum plugs in each end.

In addition to the stamped cylinder block, the crankshaft pulley, fan assembly and fan pulley and the water pump impeller and pulley are made from copper-hydrogen-brazed stampings. The cam follower guides are of SAE 4140 chromium-molybdenum steel. The camshaft is a steel forging now, but later may be made of cast iron. The crankshaft, having SAE 1045 characteristics, is centrifugally cast and is precisely counterbalanced. Piston rings are centrifugally cast and compression rings are anodized. After assembly the cylinder block is Bonderized and painted.

Every brazed joint is stronger than the parent metal. Unlike most cylinder blocks of cast iron, the engine can freeze without resulting harm because of the resiliency of the design materials. There are approximately 350 parts in the bare engine (without flywheel and front and rear bell housing, generator, starter, etc.).

Since the engine is made of metal stampings, corrosion is more of a problem and of greater importance than in a cast iron engine block. To avoid corrosion, a plastic lining material is used which has the unusual properties of being resistant to high temperatures and to nearly all chemical compounds such as might be used in an automobile cooling system.

One of the interesting experiments in the development program was the assembly of the crankshaft by brazing 25 pieces together. Though physical properties are satisfactory, at the present moment the higher cost over more conventional methods makes it prohibitive. But there is a chance that improved methods might still see the brazing method used.

The novel engine was developed in Cincinnati by Crosley engineers under the direction of Paul Klotsch, chief engineer, with the aid of Lloyd Taylor, who invented it. During the spring of 1945 one of these engines, in a generator set, was operated day and night for 1200 hr. after which only the exhaust valves needed attention due to the use of 100 octane gasoline.

The fabricated cylinder block weighs 14.8 lb. before machining, which consists of a light cut off the bottom cylinder plate and the top camshaft bearing and of boring and honing of the cylinder walls and cam follower guides.

The high economy of the engine is due in large measure to the high compression pressure. The lack of detonation is due to the cool combustion chamber where pre-ignition is prevented during the compression. The maximum wall thickness at any point separating the combustion chamber from the cooling water is 0.010 in. with 1/16 in. the usual thickness of cylinder walls. Because of the thin walls a much more even heat distribution is obtained. It permits compression ratios of 9 to 1, but actually 7.5 to 1 is used.

CONTENTS NOTED

A monthly department dedicated as a forum for the interchange of ideas between readers and editors. All readers are urged to take advantage of this space and participate in the discussions presented.

Contemporary Comments

While not a Letter to the Editor, the following excerpt from the British periodical, Engineering Inspection, *falls into the category of material for "Contents Noted:"*

"This publication (*Metals and Alloys* now MATERIALS & METHODS) leaves us always with a difficult job of selection since it covers such a comprehensive field. Vol. 21, No. 1 deals with broad surveys of materials and their applications, including fabrication methods. The testing and inspection section gives a like review of development in this field. Good contributions deal with post-formed laminated phenolic plastics and induction heating for forging and metal-powder friction materials."

It is interesting to note that this quarterly has chosen MATERIALS & METHODS *as one of the four or five American business papers and technical journals to be reviewed for its readers. The point as to our covering a comprehensive field is well taken, as that is exactly what we aim to do—cover the selection and fabrication of materials in the metalworking fields.* —The Editors.

Name Change

To the Editor:

The change in title of *Metals and Alloys* is confusing in regard to what the actual title is. On the cover, in the masthead and in the title of the statement on page 1052 of the October 1945 issue, the title is given as ENGINEERING MATERIALS & PROCESSING METHODS. In the running head and in the text, the title is MATERIALS & METHODS.

When making references to a volume, careful bibliographers, engineers, and librarians use the title as given on the title page or in the masthead. There is no doubt that references to the articles in the current numbers of the journal will appear both ways in papers and abstracts. This will cause a lot of grief to those who will wish to consult the originals in the future. We have already had, in our work at the Library, several inquiries about the correct title to use.

Morris Schrero

Carnegie Library
Pittsburgh, Pa.

Reader Schrero's comments are quite right in that our handling of the type on our front cover and elsewhere in the October and November 1945 issues led to some confusion. The correct name is MATERIALS & METHODS, *and we have changed our logotype by deleting the descriptive words "Engineering" and "Processing."* — The Editors.

Resistivity of Chromium

To the Editor:

I have been a reader of your publication MATERIALS & METHODS, née *Metals and Alloys* for a number of years and have enjoyed your articles. I can venture to say that amongst the members of my department there are many a photostatic copy in their files of such articles covering new materials and new methods.

In particular are the Engineering File Facts. Material under this heading is presented in a very convenient manner to permit filing for future reference.

This brings a point up with regard to some information contained in "Engineering File Facts No. 100" published in the December, 1945, issue entitled "Induction Heating Constants."

Some time ago in connection with some work on transmission lines for high frequency work, I had the opportunity to compare the resistivities of various metals. In particular, I was interested in those metals which had low values, hence would have low skin effect losses.

In scanning the various sources, I found that chromium had a resistivity of 2.6 microhms/cm.[3] However, in referring to the "Metals Handbook," I found that the resistivity was listed as 13.1 microhms/cm. This led me to check into the reason for such a difference and I came across the following which should be of interest to you. It has been summed up very nicely by George Dubpernell, Research Chemist, United Chromium, Inc., Waterbury, Connecticut, in his article entitled "Chromium Plating" which is printed in a special volume of The Electrochemical Society's book "Modern Electroplating" and I quote from pages 137 and 138:

"Electrical Resistivity. A commonly accepted value is 2.6×10^{-6} ohm/cm.[3] at zero C which is ascribed to Shukow. International Critical Tables also give this value, which was apparently determined on chromium powder and seems considerably too low. McLennan

(Continued on page 445)


N·A·X
HIGH-TENSILE STEEL
STRENGTH and FORMABILITY COMBINED IN ONE GREAT STEEL
GREAT LAKES STEEL
N-A-X
HIGH-TENSILE STEEL
CORP.

CONTENTS NOTED

Continued from page 443

and Niven reported the much higher resistivity of 43.8 x 10^{-6} ohm/cm.[3] at 16.8 C on a sample of electrolytic chromium in as-deposited condition. After aging or annealing, a value of 17.25 x 10^{-6} ohms/cm.[3] at room temperature was obtained. Adcock found, on measurement, that the resistivity of annealed electrolytic chromium was 13.1 x 10^{-6} ohm/cm.[3] This value is accepted as the best available in a table of physical properties of chromium metal given by Kinzel and Crafts.

"Grube and Knabe likewise measured the resistivity of electrolytic chromium and found 14.1 x 10^{-6} ohm/cm. at 20 C (68 F) for powdered metal which had been sintered in hydrogen at 1,400 C (2,552 F). Bridgman first determined the resistivity of a sample of Goldschmidt chromium under varying pressure and found the very high value of 160 x 10^{-6} ohm/cm. at 30 C and atmospheric pressure. In the second investigation a soft, swaged rod of spectroscopically pure chromium was used and a specific resistance of about 19.3 x 10^{-6} ohm/cm. at 30 C was found."

The determination of the resistivity by Shukow was made around 1900 and might have been subjected to considerable error. My own measurements on chromium plated surfaces indicate a much higher resistivity than 2.6 microhms/cm.[3]

I trust that this will prove interesting to you in the light of maintaining accurate information.

David L. Matson
Ass't Chief Development Engineer
Mechanical Development Division
Hazeltine Electronics Corp.
Little Neck, L. I., N. Y.

Mr. Matson's letter was referred to engineers of Westinghouse Electric Corp. who supplied the published data. They suggest that the value of 13.1 microhms/cm. is more in line for induction heating work.—The Editors.

Segregation of Editorial Matter

To the Editor:

I have a criticism as to the format of your magazine. The fact that the technical contents and the advertising are not separated has been very annoying and, in my opinion, detracts considerably from the potential value of the magazine for permanent binding. It is my practice to have the technical contents bound into permanent volumes and to file the advertising matter separately. Having the articles and sections run on through pages and pages of advertising, often with only one written column per page is a distinct disadvantage. The written material and the advertising are in themselves each valuable sections and should be separated.

I especially welcome material dealing with the light alloys and their methods of fabrication. Since the end of the war, the emphasis in design has been on costs. More relative data such as was presented in Materials & Methods Manual No. 1 (*Selecting Production Methods for Small Parts*) would be very useful. Relatively little information on the application of light alloys to precision casting (investment or lost wax method) has been published.

W. E. Slavens
Seattle, Wash.

The criticism of Mr. Slavens is probably the one "mechanical" criticism that is most frequently received by all publishers. The reason for this type of make-up is that publishers must accept advertisements in smaller units than full pages. Fractional-page ads always leave space which must be filled by running editorial material alongside them.

In MATERIALS & METHODS *the feature article section is kept entirely free of advertising, the problem of the two being mixed is confined largely to the departmental material.*

As to the suggestions for articles, it may be of interest to know that a forthcoming MATERIALS & METHODS *manual will cover precision casting.*—The Editors.

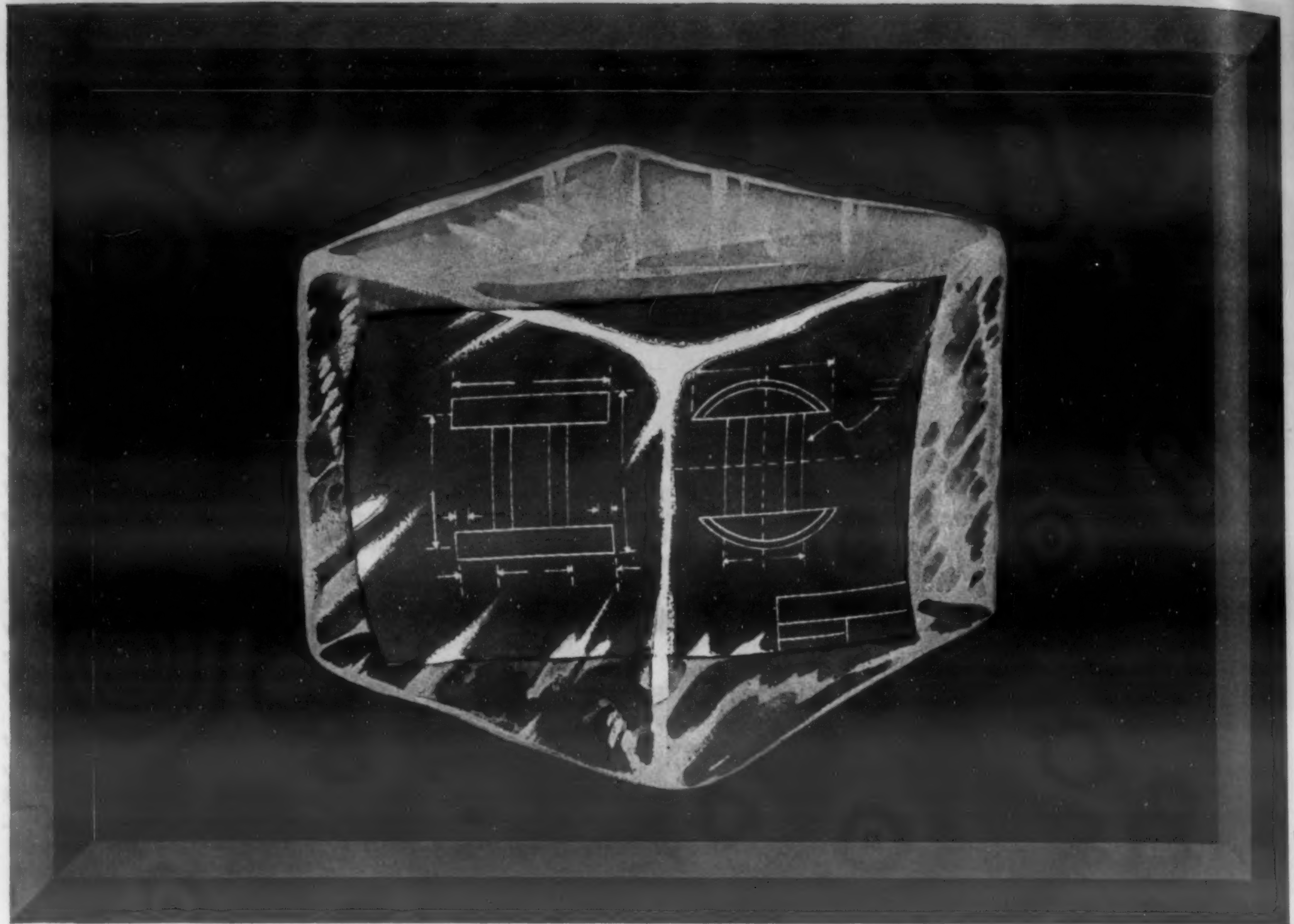
Valuable Information in Manuals

To the Editor:

I received reprints of Materials & Methods Manuals No. 6 (*Heat Treatment of Steel*) and No. 7 (*Cutting Oils*) and after reading them, I wish to state that I am very well pleased with them. Information as published in this form in your magazine is very helpful and gives MATERIALS & METHODS an added feature which cannot be secured from any other source. So saying, may I add that you keep up the good work, and the whole industry will thank you for the good your magazine has done to further the education of all its workers.

Carroll F. Bryant
Fruehauf Trailer Co.
Cedar Rapids, Iowa

We are pleased that the Materials & Methods Manuals have been so well received by industry in general. Incidentally, if any readers have subjects which they feel are worthy of the manual treatment, please let us know. If sufficient interest is shown, we will do our best to cover the subject thoroughly.—The Editors.



MATERIALS & METHODS MANUAL

12

This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal-forms or with essential principles, best procedures and operating data for performing specific metal-working processes.

Wrought Aluminum Alloys

a Guide to their Selection

by OWEN LEE MITCHELL, Metallurgist
Reynolds Metals Company

Granting that you are to use a wrought aluminum alloy—how and why should you determine which particular alloy is best for your purpose? Here you will find a complete listing of the many factors—from cost through corrosion resistance—governing the selection of wrought aluminum alloys, together with a comprehensive discussion of each major consideration. The author has purposely avoided lengthy comparisons between wrought aluminum alloys and other materials in order to furnish the clearest and most concise picture possible of aluminum and its alloys.

Contents

Materials & Methods, February, 1946
(Formerly Metals and Alloys)

Introduction

Aluminum has graduated — from minor to major importance in America's postwar opportunities. It is now being successfully employed in applications where it was not economically feasible a short time ago because suitable equipment and trained personnel, then unattainable, is now available. Literally thousands of workers, who have become skilled in the art of fabricating aluminum and its alloys, are eager to become leaders in the light metal era.

Progressive companies are continually striving to improve their products, to increase sales and to introduce cost-saving and profit-making materials. Frequently, some factor such as strength or lightness-in-weight is all important in selecting a material but in many cases other essential features are equally desirable. The use of aluminum and its alloys should be given due consideration for every application, not merely on a weight-saving basis alone, but because of its many other desirable and advantageous qualities.

It is the purpose of this article to acquaint those who may be in the position to consider the use of aluminum and its alloys with some of the fundamental information necessary to properly select the correct wrought aluminum alloy. References and comparisons to other materials have purposely been kept to a minimum. Those that have been included are thought necessary to furnish a clear, concise picture of the use of aluminum and its alloys.

The major portion of aluminum used is confined to less than 20 alloys so it is advantageous to consider the use of these alloys wherever practicable. However, it should be remembered that there are more than 100 aluminum alloys available, each with its own set of desirable properties and uses. When exceptionally unique conditions must be met it is advisable to make full use of the technical information available from the major producers.

The first step in selecting an aluminum alloy, or determining if the use of an aluminum alloy is feasible, is to list the most important qualities required, or to be considered. Some of the more important qualities and properties are:

I. Available Forms
- (a) Foil
- (b) Sheet and plate
- (c) Extruded shapes
- (d) Tubing
- (e) Rod, bar and forging stock
- (f) Wire
- (g) Rivets
- (h) Structural shapes
- (i) Special products

II. Cost Factors
- (a) Initial material
- (b) Fabrication
- (c) Reclamation
- (d) Final
- (e) Profits or returns

III. Mechanical and Physical Properties
- (a) Tensile and compressive ultimate strengths
- (b) Tensile and compressive yield strengths
- (c) Per cent elongation
- (d) Specific gravity
- (e) Moduli of elasticity
- (f) Fatigue strength
- (g) Elevated temperature properties
- (h) Ductility
- (i) Hardness
- (j) Electrical conductivity
- (k) Thermal conductivity
- (l) Coefficient of thermal expansions
- (m) Coefficient of radiant reflection

IV. Corrosion and Chemical Properties
- (a) General and pitting corrosion
- (b) Intergranular corrosion
- (c) Interfragmentary corrosion
- (d) Stress-corrosion cracking
- (e) Resistance to attack by acids, bases and salts
- (f) Resistance to attack by various chemicals
- (g) Resistance to attack by fruit juices and foods
- (h) Resistance to attack by beverages
- (i) Color and non-toxic properties of any compounds resulting from attack

V. Forming and Drawing Characteristics
- (a) Cold formability
- (b) Hot formability
- (c) Stretch forming
- (d) Hand forming
- (e) Spring-back
- (f) Forgeability
- (g) Extrudeability
- (h) Minimum bend radii
- (i) Blanking, piercing and perforating
- (j) Spinning
- (k) Stamping, embossing and coining

VI. Machining Behavior
- (a) Turning
- (b) Boring
- (c) Milling
- (d) Planing and shaping
- (e) Drilling
- (f) Tapping
- (g) Sawing
- (h) Lubricants

VII. Methods of Joining
- (a) Riveting
- (b) Gas welding
- (c) Arc welding
- (d) Multiarc welding
- (e) Spot welding
- (f) Seam welding
- (g) Push and flash welding
- (h) Brazing
- (i) Adhesives

VIII. Finishes
- (a) Natural
- (b) Mechanical
- (c) Inorganic
- (d) Organic

Alloy Nomenclature

Numeral Identification

The principal alloying element contained by an alloy is incorporated into the nomenclature of many of the aluminum alloys. The numerals indicate the chief alloying element if the suffix "S" is present.

The alloy numeral ranges, with the chief alloying element, are given in Table I.

It should be realized that practically all of the wrought alloys contain more than one intentionally added alloying element as well as the normally present impurities. There are often as many as eight elements present in an alloy.

Standard chemical compositions for various wrought alloys are given in Table II. It should be noted that 17S and R317 are different type alloys. The alloy R353 is similar to 53S while R361 is similar to 61S. The general information regarding R353 and R361 is applicable to 53S and 61S respectively.

The alloys 75S and R303 are of the aluminum - copper - magnesium - zinc type. The various properties for the two alloys, while often in the same general range, vary enough that they must be classified as two distinct and separate alloys.

TABLE I

Alloy Numeral Range	Chief Alloying Element
99.5	High-purity aluminum
2S	Commercially pure aluminum
3S-9S	Manganese
10S-29S	Copper
30S-49S	Silicon
50S-69S	Magnesium
70S-79S	Zinc
R301, R317	Copper
R303	Zinc
R353, R361	Magnesium and silicon

TABLE II — **Chemical Analysis**

Alloy	Silicon Min.	Silicon Max.	Iron Max.	Copper Min.	Copper Max.	Manganese Min.	Manganese Max.	Magnesium Min.	Magnesium Max.	Chromium Min.	Chromium Max.	Nickel Min.	Nickel Max.	Lead Min.	Lead Max.	Bismuth Min.	Bismuth Max.	Zinc Max.	Titanium Max.	Others Each Max.	Others Total Max.	Aluminum
2S			1.0*		0.20		0.10											0.10		0.05	0.15	99.0 Min.
3S		0.60	0.70		0.20	1.0	1.5											0.10		0.05	0.15	Remainder
11S		0.40	0.70	5.0	6.0									0.20	0.60	0.20	0.60	0.30		0.05	0.20	Remainder
14S	0.50	1.2	1.0	3.9	5.0	0.40	1.2	0.20	0.80		0.10							0.25	†	0.05	0.15	Remainder
17S		0.80	1.0	3.5	4.5	0.40	1.0	0.20	0.80		0.25							†0.10	†	0.05	0.15	Remainder
R317		1.0	1.0	3.5	4.5	0.40	1.0	0.20	0.80		0.25			0.30	0.70	0.30	0.70	†0.10	†	0.05	0.15	Remainder
A17S		0.80	1.0	2.0	3.0		0.20	0.20	0.50		0.25							0.10		0.05	0.15	Remainder
18S		0.90	1.0	3.5	4.5		0.20	0.45	0.90		0.10	1.7	2.3					0.25	0.15	0.05	0.15	Remainder
24S		0.50	0.50	3.8	4.9	0.30	0.90	1.2	1.8		0.25							0.10		0.05	0.15	Remainder
Clad 24S Core		0.50	0.50	3.8	4.9	0.30	0.90	1.2	1.8		0.25							0.10		0.05	0.15	Remainder
Clad 24S Cladding			*0.70		0.10		0.05											0.10				99.3 Min.
25S	0.50	1.2	1.0	3.9	5.0	0.40	1.2		0.05		0.10							0.25	0.15	0.05	0.15	Remainder
32S	11.0	13.5	1.0	0.50	1.3		0.20	0.80	1.3		0.10	0.50	1.3					0.25	0.15	0.05	0.15	Remainder
A51S	0.60	1.2	1.0		0.35		0.20	0.45	0.80	0.15	0.35							0.25	0.15	0.05	0.15	Remainder
52S			*0.45		0.10		0.10	2.2	2.8	0.15	0.35							0.10		0.05	0.15	Remainder
53S R353	45%-65% of Magnesium		0.35		0.10		0.10	1.1	1.4	0.15	0.35							†0.10	†	0.05	0.15	Remainder
56S		0.30	0.30		0.10	0.05	0.20	4.5	5.6	0.05	0.20									0.05	0.15	Remainder
61S	0.40	0.80	0.70	0.15	0.40		0.15	0.80	1.2		0.35							0.10	0.15	0.05	0.15	Remainder
R361	0.40	0.80	0.70	0.15	0.40		0.15	0.80	1.2		0.35							0.25	0.15	0.05	0.15	Remainder
R301 Core	0.50	1.2	1.0	3.9	5.0	0.40	1.2	0.20	0.80		0.25							0.25		0.05	0.15	Remainder
R301 Cladding	0.35	1.0	0.60		0.10		0.75	0.80	1.5		0.35							0.10	0.10	0.05	0.15	Remainder
75S	Aluminum-Copper-Zinc-Magnesium Type Alloys																					
R303																						

* Silicon plus Iron   † Maximum of 0.25% Zinc and 0.15% Titanium permitted in Forgings and Forging Stock

Prefixes and Suffixes

The suffix "S", following the alloy number, indicates it is a wrought alloy. However, wrought alloys in the R300 series do not carry the suffix "S".

The prefixes "M" and "X" are used to indicate alloys that are in experimental stages.

Prefixes other than "R", "M" or "X" indicate a modification of the original chemical composition. The prefix "A" indicates the first modification, the prefix "B" the second modification and so on. An example is the alloy 51S, the original composition of which was changed by the addition of chromium and is known to the trade as A51S.

Suffixes are also used to indicate the tempers of the various alloys, which in turn depend upon the methods used to strengthen the alloy.

Temper Designation

The wrought alloys are divided into two broad groups—the "common" or "nonheat-treatable" alloys and the "strong" or "heat-treatable" alloys.

The nonheat-treatable group of alloys consists of those that contain elements that remain substantially in solid solution or form constituents that are insoluble. The major alloys in this group are the high-purity alloys such as 99.75, 99.5, foil, reflector sheet and the alloys 2S, 3S, 43S, 52S and 56S.

The heat-treatable group of alloys consists of those that contain elements, groups of elements or constituents that have considerable solid solubility at elevated temperatures and limited solubility at lower temperatures. The major alloys in this group are the high copper-bearing alloys R301, 14S, 17S, R317, 24S, 25S and 27S; the magnesium silicide type alloys A51S, 53S, R353, 61S and R361; and the high zinc-bearing alloys R303, 75S and 76S.

The strengths of the nonheat-treatable alloys are obtained by alloying and by plastic deformation. Alloys in the fully-annealed condition are referred to as being in the "O" condition. When sufficient cold work has been performed to increase the tensile strength to the maximum commercially feasible, the alloy is referred to as being in the "H" or fully-hardened temper. The intermediate tempers ¼H, ½H and ¾H are produced by subjecting the common alloy to plastic deformation to such a degree that the tensile strength is increased, above the annealed ("O") properties, by the appropriate fraction of the overall increase in strength commercially feasible by such methods (i.e. the difference between the "H" and the "O" tensile strengths).

The strengths of the heat-treatable or strong alloys are increased primarily by thermal treatments. After these alloys are fabricated to the desired thickness and shape they are subjected to a solution heat-treatment which consists of bringing the product up quickly to a predetermined temperature, holding at this temperature a sufficient length of time to allow practically all of the soluble elements and constituents to go into solid solution, and then rapidly quenching to prevent, or retard, precipitation from the then supersaturated solid solution.

The alloys 17S and 24S are known as natural aging alloys since they "precipitation harden" at room temperature. The rest of the more commonly used heat-treatable alloys, while subject to various degrees of natural aging, require "artificial" aging (precipitation thermal treatment) at slightly or moderately elevated temperatures to obtain their maximum properties.

The heat-treatable alloys in the fully-annealed temper are referred to as being in the "O" temper. Immediately after they have been subjected to a solution heat-treatment they are referred to as being in the "freshly quenched" condition.

The alloys that require an artificial aging treatment age a limited amount at normal temperatures, the amount depending upon the alloy. Some of these alloys reach their *natural* aging strengths a few days after quenching and are referred to as being in the "W" temper. Others continue to age over an extended period and cannot be stocked in the "W" temper. After aging, either naturally or by a thermal treatment, the alloys are referred to as being in the "T" temper.

Products such as sheet receive a slight amount of cold work during the flattening and straightening operations after solution heat-treatment. When these operations are eliminated or kept to a minimum the material is referred to as being in the "UT" temper.

Material that is cold worked after receiving solution heat-treatment and aging treatments is referred to as being in the "RT" temper.

Material that receives no thermal treatment after the final plastic deformation operations is referred to as being in the as-fabricated or "F" condition. The suffixes "R" and "AR" are also occasionally used to indicate this temper in rolled material.

Several alloys, in sheet form, consist of a comparatively strong core protected with surface layers of material that furnish anodic protection to the core material. If the protective layers are high-purity aluminum, the Reynolds Metals Company's product is known as "Pureclad". If the layers are another alloy, the term "Clad" is used. The term "Alclad" is used by some producers to designate all cladded alloys regardless of their compositions.

Available Forms

Aluminum is universally regarded as being the most easily formed and worked of the structural metals, being available in practically every form and shape. In Table III are listed the various forms produced in the popular wrought alloys.

Selection of Form

Those who are more familiar with other common metals, than with aluminum, often fail to realize the flexibility of the aluminum alloys. Since they are available in practically every form and shape, it is sometimes difficult to select the most desirable and advantageous form.

The most popular aluminum commodities are sheet and plate. Their uses and applications are so well known that they need no amplification.

Cladded sheet is used when superb resistance to corrosion is desired; the alloys being as resistant as their protective layer. The subject is discussed fully under Corrosion and Chemical Properties.

Many shapes and angles can be produced by forming from sheet material as well as by the extrusion process. Large complex sections are generally cheaper when extruded. However, many angles and shapes, formed from

sheet material, compete favorably with extruded shapes in cost.

There are available many standardized shapes which are stock items and should be used whenever practicable. If an appreciable quantity is to be used it is wise to purchase the shape that is most suitable for your use. Extrusion dies are so inexpensive, often costing less than $75.00, that it is generally more economical to have them made to your specifications.

Extruded shapes can be used instead of extra heavy plate when relatively narrow widths are required. This is generally preferred over the use of two plates of lighter thicknesses. The thickness of the extruded section, however, must be at least 15% of the width.

The main advantage of using an extruded shape is that almost any contour can be obtained, permitting superior engineering with a reduction of weight and minimizing costly machining operations.

Foil

Aluminum that has been rolled to a thickness of 0.005-in. or less is known as foil. Generally this is not recognized as a wrought product simply because the field is so complex and diversified that it has been found advantageous to consider it as a special division. Foil is commercially being produced with thickness varying from 0.00017 to 0.005-in.

Sheet and Plate

Thicknesses between 0.005-in. and 0.250-in. are classified as sheet. Aluminum that has been rolled to a thickness of 0.250-in. or greater is known as "plate" although some of the older specifications consider 0.250-in. material as sheet. The term "strip" at one time designated a method of manufacture. It was later used to denote narrow widths of sheet. The term is now obsolete.

Sheet (0.102-in. or less in thickness) is produced in both "flat" and "coil" form. The methods of manufacture and handling are somewhat different allowing, with some alloys, a price differential in favor of the coiled product.

Both flat and coil sheet can be furnished in several finishes. When no special precautions or extra processes are employed, the material is referred to as having a *mill finish*. This finish may vary from dull to bright depending upon fabricating conditions.

Some applications require a nonheat-treatable alloy with a surface luster on

Much aluminum is made in the foil form for uses such as wrapping foods to keep them fresh.

TABLE III **Wrought Forms Available in Popular Alloys**

Alloy	Sheet	Plate	Extruded Shapes	Tubing	Rod & Bar	Forging Stock	Rolled Shapes	Rivets	Wire
2S	•	•	•	•	•			•	•
3S	•	•	•	•	•			•	•
11S					•				•
14S			•			•	•		
17S	•	•	•	•	•	•	•	•	•
A17S								•	•
R317					•	•			•
18S						•			
24S	•	•	•	•	•			•	•
Pureclad 24S†	•	•							
25S						•			
32S						•			
A51S						•			
52S	•	•	•	•	•				•
53S, R353	•	•	•	•	•	•	•	•	•
56S								•	•
61S, R361	•	•	•	•	•				•
70S						•			
R301	•	•							
R303			•						
75S			•						
Alclad 75S	•	•							

* Commodities regularly produced
† Also Alclad 24S

Aluminum is finding considerable use in reducing weight of railroad cars, both passenger and freight.

one side. This condition is met by a controlled finish classified as *mill-finish-one-side-bright* or commercial-finish-one-side-bright. *Standard-finish-one-side-bright* or special-finish-one-side-bright sheet is a controlled finish with little variance between sheets. This finish is much brighter than the mill-finish-one-side-bright, possessing a high degree of luster *and* depth of brightness. Where these qualities are furnished on both sides of the sheet, the material is referred to as *standard bright finish two sides* or special-two-sides-bright. The term *dull finish* refers to an uncontrolled dull mill finish while the *gray plate* finish is a controlled dull gray matte-like mill finish.

The *standard bright finishes* require careful production control and demand a premium price. The degree of brightness is dependent upon the temper and the grade. The relative brightnesses, in decreasing order are: (1) "H" or fully-hardened temper, (2) "O" or annealed temper, (3) ¾H temper, (4) ½H temper, and (5) ¼H temper. The heat-treatable alloys are available only in the regular mill finish.

Extruded Shapes

Extruded shapes are available in many forms and alloys. Commercial sizes range in thickness from 1/16 to 14 in., with lengths varying from inches to more than 80 ft. The maximum weight of an extruded shape is generally limited to 350 lb.

Most of the nonheat-treatable alloys and some of the weaker heat-treatable alloys can be extruded through port-hole dies, permitting the production of hollow extrusions in many intricate shapes. A very good example of the use of such a shape is in the production of hinges. The hole for the pin is produced during the extrusion process by employing a port-hole die, thereby reducing the number of operations necessary to produce the finished hinge.

Tubing

Seamless aluminum tubing is produced from hollow tube blooms extruded from drilled, pierced or hollow "as-cast" ingots, the blooms being fabricated to size by means of tube reducers, draw benches or a combination of both.

The lengths of the smaller sizes of tubing are limited by the available fabricating equipment, but some sizes have been produced in 80-ft. lengths. As a general rule, however, the maximum commercial straight-lengths are approximately 30 ft. if subsequent thermal treatments are required.

The size of tubing is controlled by the outside diameter, the inside diameter and the wall thickness. It can be furnished with very close tolerances for any two, but not all three of these dimensions.

Tubing is obtainable in many diversified shapes including round, square, rectangular and tear-drop. Heavy-walled tubing can be furnished with an inside taper.

Rod and Bar

Rod and bar stock is divided into two broad classifications—the forging and the non-forging groups. The non-forging group can be further subdivided into nonheat-treatable and heat-treatable classes.

The nonheat-treatable class is furnished in the ("O") annealed condition and the ("F") as-fabricated condition. With the exception of 52S, they possess excellent welding qualities but are inferior to the heat-treatable group in machinability. Strengths are naturally limited.

The heat-treatable class is furnished in all of the appropriate tempers. These alloys possess machining qualities superior to the nonheat-treatable class. Many of the alloys, such as 11S and R317 possess excellent machining properties and are very popular. The term "screw machine stock" is sometimes used to denote a free-machining product with broader surface standards but the term has not been accepted throughout the industry and should be avoided.

Forging Stock

Aluminum alloy forging stock is available in a variety of forms to fill every forging requirement. Round sections having a diameter of 3/8 in. or

more are classified as *forging rod*. Square, rectangular, hexagonal and octagonal cross-sectioned stock, having a greatest-distance-across-flats of 3/8 in. or more, is referred to as *forging bar*, while forging stock having other shapes is called *forging shapes*. Any forging section that is less than 3/8 in. across its greatest dimension is called *wire*.

Forging stock is supplied in the "as fabricated" condition; consequently the material is *always* specified as forging stock to avoid confusion with similar type material that is to be used for other applications. This type of material receives a very critical inspection, generally being caustic etched to detect even minor surface defects.

There are two manufacturing processes commercially employed to produce forging stock. Forging rod is usually rolled while the shapes are generally extruded. Forging bar is produced by both processes. Most rod and bar material can be furnished in either the hot- or cold-finished condition. The shapes are usually furnished in the as-fabricated condition.

Forging stock is divided into two classes. Class I is generally hot-finished and is satisfactory for most forgings. Class II is cold-finished to very close tolerances for applications requiring rigid volume control.

Rolled Shapes

Many shapes can be produced by rolling or by extruding. In such cases, the mills usually use the method more desirable. However, the large structural channels and I-beams must be produced by rolling processes. Information regarding availability and sizes should be obtained from the major producers.

Wire

Wire is often classified as the group containing all shapes whose largest-distance-across-flats, or diameter, is less than ⅜ in. but this is not strictly true as slitted wire is often considerably wider. The major portion of the wire produced is round, although it is also produced in special forms such as welding wire, flattened wire, flattened and slit wire and half-round wire.

One of the major uses of wire is in the manufacture of rivets. The alloys used to produce these commodities are given in Table III.

Cost Factors

Cost is generally one of the most important items to consider when determining what material shall be used. As a rule, metals are purchased on a weight basis, so conversion to volume or surface area is often necessary when comparing costs. In addition, when using an aluminum alloy it may be desirable to change the design of a product or a part. Sometimes the part will have to be increased in size, or the contour changed, to gain strength or rigidity; sometimes the size can be decreased or the piece incorporated with another. As a general rule, from ⅓ to ½ as much aluminum as steel, by weight, will be required.

Very little general information can be correctly stated regarding fabricating costs when employing aluminum alloys. Aluminum is one of the most easily worked of all metals and, step by step, is at least comparable in cost to any of them. One very favorable asset is that the aluminum alloys are available in almost any conceivable form, often permitting drastic changes in fabrication procedures.

Aluminum lends itself favorably to mass production applications, particularly those which incorporate automatic equipment. Such applications should be especially considered when the volume is sufficient to warrant expenditure for necessary equipment.

The production of many products is such that the reclamation of rejections means the difference between profit and loss. Articles produced from aluminum alloys generally show high salvage values. In addition, aluminum scrap is readily sold at a high resale value.

Final cost, of course, takes all of the above into consideration. Ofttimes the cost, when using an aluminum alloy, appears to be higher than for other materials until new and cheaper procedures, which are generally synonymous with fabricating experience, bring the cost to new low levels.

While original cost is admittedly of prime importance, such features as lightness, maintenance, strength, sales appeal and attractiveness play such an important role in consumer sales that it is often advantageous to employ an aluminum alloy even when the final cost of the product is slightly increased.

The use of aluminum and its alloys is not confined to finished articles alone, as it often contributes to the manufacture of wholly unrelated products. Their use can often shorten batch operations and wash-up time—save human effort and mechanical power—reduce the weight of mobile equipment or protect a flavor, taste or color. These, and many other factors, go far in reducing the price of a wholly unrelated product.

The price of the various aluminum alloys vary greatly, depending upon the form, the degree of alloying, the fabricating procedures required and the ease of production. The nonheat-treatable alloys such as 2S and 3S are less expensive than the "heat-treatable" alloys. The alloys that are produced in large quantities are also cheaper and should be used whenever practicable.

Mechanical and Physical Properties

Tensile Strengths

The ultimate tensile strength of an aluminum alloy is, by definition, the maximum tensile stress, in pounds per square inch of cross-sectional area, required to rupture a standard test specimen.

Aluminum has no definite yield point but the yield strength, by definition, is considered to be the stress, in pounds per square inch of cross-sectional area, required to produce a per-

TABLE IV Mechanical Properties of Wrought Aluminum Alloys

Alloy and Temper	Tension				Hardness	Shear	Fatigue
	Strength p.s.i.		Elongation in 2 In. %		Brinell Number 500kg load 10mm ball	Shearing Strength p.s.i.	Endurance Limit p.s.i.
	yield (set 0.2%)	ultimate	0.064 in. thick specimen	0.505 in. diameter specimen			
2S-O	5,000	13,000	35	45	23	9,500	5,000
2S-¼H	13,000	15,000	12	25	28	10,000	6,000
2S-½H	14,000	17,000	9	20	32	11,000	7,000
2S-¾H	17,000	20,000	6	17	38	12,000	8,500
2S-H	21,000	24,000	5	15	44	13,000	8,500
3S-O	6,000	16,000	30	40	28	11,000	7,000
3S-¼H	15,000	18,000	10	20	35	12,000	8,000
3S-½H	18,000	21,000	8	16	40	14,000	9,000
3S-¾H	21,000	25,000	5	14	47	15,000	9,500
3S-H	25,000	29,000	4	10	55	16,000	10,000
52S-O	14,000	29,000	25	30	45	18,000	17,000
52S-¼H	28,000	34,000	12	18	62	20,000	18,000
52S-½H	29,000	37,000	10	14	67	21,000	19,000
52S-¾H	34,000	39,000	8	10	74	23,000	20,000
52S-H	36,000	41,000	7	8	85	24,000	20,500
14S-O	14,000	27,000	—	18	45	18,000	11,000
14S-W	40,000	56,000	—	25	100	34,000	18,000
14S-T	60,000	70,000	—	13	135	42,000	18,000
R301-O	10,000	25,000	22	—	—	—	—
R301-W	41,000	62,000	19	—	—	—	—
R301-T	60,000	68,000	10	—	—	43,000	12,500
17S-O	10,000	26,000	20	22	45	18,000	11,000
17S-T	40,000	62,000	20	22	100	36,000	15,000
24S-O	10,000	26,000	20	22	42	18,000	12,000
24S-T	45,000	68,000	19	22	105	41,000	18,000
24S-RT	55,000	70,000	13	—	116	42,000	—
[a]Pureclad 24S-T	41,000	62,000	18	—	—	40,000	—
[a]Pureclad 24S-RT	50,000	66,000	11	—	—	41,000	—
25S-T	35,000	57,000	18	—	—	—	—
R353-O 53S-O	7,000	16,000	25	35	26	11,000	7,500
R353-W 53S-W	20,000	33,000	22	30	65	20,000	10,000
R353-T 53S-T	33,000	39,000	14	20	80	24,000	11,000
R361-O 61S-O	8,000	18,000	22	—	30	12,500	8,000
R361-W 61S-W	21,000	35,000	22	—	65	24,000	12,500
R361-T 61S-T	39,000	45,000	12	—	95	30,000	12,500
R303-O	15,000	30,000	18	18	—	—	—
[b]R303-T315	77,000	82,000	—	11	145	48,000	22,500
[b]R303-T275	84,000	89,000	—	10	145	48,000	22,500
[c]Clad R303-T315	65,000	72,000	9	—	—	—	—
[c]Clad R303-T275	69,000	75,000	9	—	—	—	—
[b]75S-O	20,000	40,000	—	12	—	—	—
[b]75S-T	80,000	88,000	—	10	150	47,000	22,500
[c]Alclad 75S-O	14,000	32,000	16	—	—	—	—
[c]Alclad 75S-T	66,000	76,000	11	—	—	46,000	—

[a] Includes Alclad [b] Extruded Shapes [c] Sheet

manent set of 0.2%. In several foreign countries the term "proof stress" is employed using a permanent set of 0.1%. Typical mechanical properties for the various alloys are given in Table IV.

Compressive Strengths

It is generally accepted that the compressive yield strengths of the aluminum alloys are slightly less than the corresponding tensile yield strength. The method of testing and the shape of the specimen have a decided influence on the compressive yield strength obtained since it is affected by the slenderness ratio (ratio of length to cross-sectional area) of the specimen. The thermal history is also important. The guaranteed minimum mechanical properties are set with this difference taken into consideration; nevertheless technical information is available, upon request, for applications demanding high compressive mechanical properties.

Elongation

One measurement of the ductility of aluminum is the per cent elongation. With sheet, extrusions and similar products, the value is given as the per cent elongation in 2 in. When it is not feasible to use this gage distance, the value is measured over a length equal to 4 times the diameter of the test specimen.

It should be recalled that the per cent elongation depends upon the distance over which it is measured. For example, a test specimen from 24S-T sheet material, which has an elongation in 2 in. of 20%, will have an elongation of approximately 30% when measured over a gage distance of ¼ in. The per cent elongation is dependent upon the shape of test specimen.

Property Range

It is readily apparent that there are several alloys and tempers available for every mechanical property range applicable to the aluminum alloys. High-purity aluminum, in the annealed condition, is so soft that it can be cut with a knife; R303-T275 has a yield strength twice that possessed by structural steel.

Thus the choice of alloy, in any mechanical property range, will depend upon the form necessary and the other characteristics desirable. Generally, the use of a nonheat-treatable alloy is advantageous whenever practicable. If the use of a heat-treatable alloy is desirable, it will be found advantageous to consider the use of "W" or "T" tempers since a subsequent heat-treatment is avoided.

In many applications, the use of aluminum alloys in the "W" temper is feasible. For example, R301-W is finding many industrial uses where existing regulations demand that the maximum yield strength be not in excess of 80% of the tensile strength. A special aging treatment also permits the use of R361 and 61S for such applications. The condition is sometimes encountered when an aluminum alloy displaces a ferrous product.

The guaranteed minimum (or maximum) mechanical properties of an alloy may vary with the different products or even between the different size-ranges of a product. This is due mainly to the manufacture and testing methods employed, with a substantial portion of the variation being due to shape of the test specimens rather than fundamental changes in the mechanical properties of the metal.

Testing

Sheet products are tested at 90-deg. (cross-grain) to the direction of rolling and straightening, with the exception of the intermediate tempers of the nonheat-treatable alloys, because the mechanical properties are slightly lower in this direction. The with-grain mechanical properties of sheet material are higher due to preferred orientation, the elongation of the grains, and the straightening and stretching operations necessary to produce a flat sheet. The intermediate tempers of *common* alloy sheet are tested "with-grain" as there is a greater fluctuation of properties in this direction. Shapes, tubing, rod, wire and similar products must be tested in the longitudinal direction.

The differences that exist between the guaranteed minimum mechanical properties of flat and coil sheet are due primarily to the elimination of the straightening and flattening operations. The mechanical properties of reheat-treated material may be lower for the same reason.

Specific Gravity

The specific gravity of commercially pure aluminum (2S) is 2.71, corresponding to a weight of 0.0979 lb. per cu. in. or roughly a tenth of a lb. per cu. in. The folowing conversion factors may be used to determine the weights of the commonly used aluminum alloys and metals:

0.993 x wt. of 2S = wt. of 32S, A51S, 53S and R353
0.996 x wt. of 2S = wt. of 61S and R361
1.01 x wt. of 2S = wt. of 3S
1.02 x wt. of 2S = wt. of 24S and R301
1.03 x wt. of 2S = wt. of 14S, 17S, 18S, 25S and R317
1.04 x wt. of 2S = wt. of R303
2.6 x wt. of 23 = wt. of zinc
2.9 x wt. of 2S = wt. of steel
3.1 x wt. of 2S = wt. of brass
3.3 x wt. of 2S = wt. of copper and nickel

TABLE V — **Comparative Strength-Weight Ratios**

Material	Specific Gravity	Density lb/in.^{3}	Tensile Strength p.s.i.	Specific Tensile Strength [a]	Yield Strength p.s.i.	Specific Yield Strength [b]
Aluminum (R303-T275)	2.8	0.10	74,000	26,400	69,000	24,600
Aluminum (R301-T)	2.8	0.10	64,000	22,800	57,000	20,400
Stainless Steel (Austenitic 18:8 full hard)	7.8	0.28	185,000	23,700	140,000	17,900
Magnesium (J-H)	1.8	0.07	40,000	22,200	32,000	17,800
Cr-Mo Alloy Steel (SAE 4140)	7.8	0.28	156,000	20,000	131,000	16,800
Aluminum (24S-T)	2.8	0.10	64,000	22,800	42,000	15,000
Brass (67% Zn-33% Cu)	8.3	0.30	75,000	9,000	55,000	6,600
Structural Steel	7.8	0.28	60,000	7,700	35,000	4,500

[a] Ratio of Tensil Strength to Specific Gravity [b] Ratio of Yield Strength to Specific Gravity

Specific gravities of the various materials become of interest in applications where conservation of weight is important. A convenient method of comparison is by the use of strength-weight ratios. It should be realized that this comparison does not take into consideration the all-important fabricating characteristics. Comparative strength-weight ratios for several aluminum alloys and other metals are listed in Table V.

Moduli of Elasticity

The ratio of stress (load), in lb. per sq. in., to strain (elongation), in in. per in., in the elastic range under tensile conditions is known as Young's Modulus of Elasticity. For wrought aluminum alloys this constant is between 10,300,000 and 10,500,000 p.s.i. The ratio of shear stress to shear strain, which is known as the Modulus of Rigidity, is approximately 3,850,000 for the aluminum alloys.

Young's Modulus for steel is approximately 30,000,000 p.s.i., or roughly three times the value for the aluminum alloys. This means that, within the elastic range, a section of aluminum will deflect or stretch three times as much as a similar section of steel under identical conditions, making it necessary to use a different design when comparable deflections characteristics are required.

The degree of deflection is inversely proportional to the product of Young's Modulus and the moment of Inertia. Consequently, it is usually desirable to increase the moment of Inertia, by employing thinner and deeper sections of aluminum alloys, when equal deflections are required.

The above comparison is, of course, on a volume basis. On an equal weight basis, the aluminum alloys deflect about one-seventh as much as steel. For equal deflections, the weight of aluminum required is approximately one-half that required for steel. Similar comparisons hold true for critical loads on long columns.

The increased deflection, by volume, of the aluminum alloys, caused by lower moduli of elasticity, is offset by their increased ability to absorb impact without permanent set, and to reduce stresses produced by fixed deflections. Their ability to absorb energy from dynamic loads is even greater. As an example, for equal elastic strengths, the strong aluminum alloys on a weight basis, will absorb approximately eight times as much energy as steel. By volume, the energy absorption of aluminum is three times as much as steel.

Fatigue Strengths

The endurance (fatigue) limit of an aluminum alloy is the maximum stress that can be applied to a specimen for 500,000,000 completely reversed cycles, at a speed of 10,000,000 r.p.m., without fracture. Fatigue values, ranging from 5,000 p.s.i. for 2S-O to more than 22,000 p.s.i. for the high zinc-bearing alloys are given in Table IV.

Effect of Elevated Temperatures

Aluminum alloys, like other metals, when subjected to elevated temperatures, possess lower tensile strengths, yield strengths, and moduli of elasticity and higher per cent elongations. When exposed to sub-zero temperatures, the mechanical properties and the per cent elongation of aluminum increase. In-

Breaking down a 2-ton sheet ingot with a 4-high reversible hot mill.

creased impact values have been reported at temperatures lower than −300 F.

Overaging or improper aging of the heat-treatable alloy may occur on prolonged exposure to elevated temperatures, resulting in impaired resistance to corrosion or changes in mechanical and physical properties. The alloys 18S and 32S, which contain nickel as a minor alloying element, possess exceptionally good properties and resistance to corrosion at elevated temperatures, but the natural aging alloys 17S and 24S often have less resistance to corrosion after short time exposures.

Erichsen Tests

The Erichsen cup test is used occasionally as a relative index of ductility, and to a minor degree to denote the drawability of the aluminum alloys. The values are a measurement of the gage and depth of the formed cup in millimeters. The surface of the material influences the values obtained to such a degree that they are, at best, only an indication of the ductility. The use of the test is recommended only for an indication or a comparison of properties or to obtain a quick check on grain size. Care should be taken when obtaining grain size in this manner as clad products and heavy gages of sheet sometimes show a false grain size because of a surface layer of coarse grains.

Hardness

The use of various hardness tests as a *control* of plant heat-treatment and to distinguish between different tempers and alloys has proved successful even though the property ranges of the intermediate tempers of the common alloys overlap. Also, the Brinell hardness test is commercially employed for forgings. Otherwise, the use of any hardness test, for other than comparison, is considered poor practice.

There are many reasons for the inability to utilize the hardness tests on a general commercial basis for all wrought aluminum alloys. The hardness of a material is a measurement of many physical and mechanical properties instead of one or a few. The "strong" alloys contain appreciable amounts of alloying elements and gain a large portion of their strength by precipitation hardening. The degree of this precipitation can not be accurately evaluated by hardness tests. In addition, clad products contain a layer of softer material which precludes the commercial use of hardness tests for determining any specific property.

There have been many attempts to correlate hardness values with ultimate tensile strengths, with varying degrees of success. The ratio of tensile strength to Brinell hardness is partially dependent upon the alloy, the degree of solution of soluble constituents and the amount of cold work, varying from 450 to 625.

Published hardness values are those obtained with Brinell instruments employing a 10 mm. ball and a 500 kg. load. These values are subject to considerable error especially near the low end of the scale. The Rockwell tester is preferred by many and is extensively used in mill production. However, it is imperative that there is no anvil effect when testing thin gage material. The Vickers tester, the Barcol Impressor and the Webster Hardness Gage are also being successfully employed to secure comparative values. Brinell values are listed in Table IV.

Electrical Conductivities

The electrical conductivities of the various aluminum alloys depend largely upon the amount and type of the elements in solid solution, the undissolved elements or insoluble constituents exerting only a minor effect. Pure aluminum, by volume, has an electrical conductivity of approximately 64% of the International Annealed Copper Standard. However, on a weight basis, the conductivity is more than 210% of the international standard. Furthermore, the alloys are para-magnetic and non-sparking.

High-purity aluminum is generally employed when a very high electrical conductivity is desired. Strength, if necessary, is obtained by the use of an additional aluminum alloy, or another structural metal.

The excellent weight-conductivity of aluminum is often utilized in the production of power transmission cables.

Since high-purity metal is a prerequisite, the necessary strength is obtained by the use of a steel wire center. This combination permits a substantial savings in weight and expense.

Thermal Conductivity

High-purity aluminum (99.66% Al) has a thermal conductivity of 0.52 calories per sec., per square centimeter, per centimeter of thickness, per degree Centigrade at 50 C (122° F), or approximately 1510 B.t.u.'s per hr., per sq. ft., per in. of thickness, per degree Fahrenheit. As with the electrical conductivities, the thermal conductivities are decreased by increasing amount of elements in solid solution and degree of cold plastic deformation.

Expansion

The room temperature coefficient of thermal expansion of commercially pure aluminum (2S) and 3S is 0.0000133 per deg. F, or approximately double that possessed by cast iron and steel. The coefficient is approximately 0.000013 for the magnesium-bearing alloys, approximately 0.000012 for the high copper-bearing alloys and from 0.0000108 to 0.000012 for the silicon-bearing alloys. These relatively large coefficients, however, do not preclude the use of aluminum with other metals, such as steel, which have substantially lower coefficients.

Reflectivity

Many applications of aluminum utilize its high reflectivity. Highly polished high-purity aluminum is widely employed as reflectors because of its high specular and semi-specular reflectivity, the reflection factors being as high as 85%. Specular reflection allows light to be reflected where it is desired instead of being diffused over a wide area. The high thermal conductivity of aluminum disperses the heat generated by the light source, producing more desirable operating conditions.

The high-purity alloys, or a common alloy clad with high-purity metal are used when maximum reflectivity is required.

Corrosion and Chemical Resistance

Corrosion Resistance

The study of the corrosion, or rather the resistance to corrosion, of any metal is a life-time occupation. In the case of aluminum and its alloys, so much information has been published about their behavior under extremely severe laboratory-produced corrosive conditions that those unfamiliar with such alloys are often inclined to doubt the advisability of their use for many applications. Such fears are, of course, utterly unfounded, but a knowledge of the types of corrosion possible with the various wrought aluminum alloys and their resistance to conditions conducive to such attacks is essential for the proper choice of alloy. Actually, the choice of the proper alloy, from a resistance to corrosion standpoint, is simple; and the superb resistance to corrosion is one of the major assets of the aluminum alloys.

Aluminum has a high affinity for oxygen, quickly forming a protective oxide film upon exposure to an oxygen-bearing atmosphere. This film, estimated to be approximately 0.0000005 in. thick, prevents further attack unless removed or penetrated by chemical or mechanical means. It is this characteristic that furnishes aluminum and its alloys their resistance to corrosion.

The invisible, tightly adherent and practically impervious film must be penetrated before corrosion can occur. Since the thickness of the oxide film determines, to a large degree, the time necessary for penetration and corrosive attack, chemical and electrical methods, which artificially increase the thickness of the film, are widely employed to gain additional protection. These processes are described under finishes.

When aluminum and its alloys are not immune to corrosion under a specific set of conditions, control of the type of corrosive attack becomes important. It is desirable that corrosion be of the general pitting type since this type has the least affect on mechanical properties. Intergranular corrosion rapidly reduces the effective cross-sectional area and can cause premature failure due to stress.

Practically all types of corrosion prevalent in aluminum alloys—other than chemical attack—are caused by galvanic action. The conditions necessary for such an attack are at least two areas of different potentials connected by an electrolyte. Water, contaminated with chlorides or salts, is generally the electrolyte. The areas of different potentials can be dissimilar metals or alloys, constituents out of solution, inclusions or similar non-homogeneous material.

When corrosion occurs by galvanic action the current flows from the *anodic* areas to the *cathodic* areas. Aluminum is dissolved at the anode but immediately reacts, forming aluminum hydroxide which precipitates (in neutral solutions) around the anodic area. Hydrogen is evolved at the cathode, which is not attacked.

It is apparent that aluminum and its alloys, in the presence of an electrolyte, should not be used in direct contact with metals that are appreciably more cathodic. If at all practicable, the metals should be protected by paint or other suitable means. When the metals must be connected without protection, a large anodic area, in comparison to the cathodic area, should be employed.

Galvanic corrosion can occur even when the aluminum alloys are not in contact with dissimilar metals. The different alloys are produced by employing combinations of elements such as silicon, iron, copper, magnesium, manganese, zinc, chromium and titanium. Special alloys may also contain nickel, lead and bismuth. Lead and bismuth are insoluble in aluminum. Chromium, magnesium and manganese either increase or have no appreciable detrimental effect on the resistance to corrosion, depending upon the alloy and application. Silicon generally decreases the resistance to corrosion slightly. Iron, copper and tin decrease aluminum's resistance to corrosion, unless corrective elements are present.

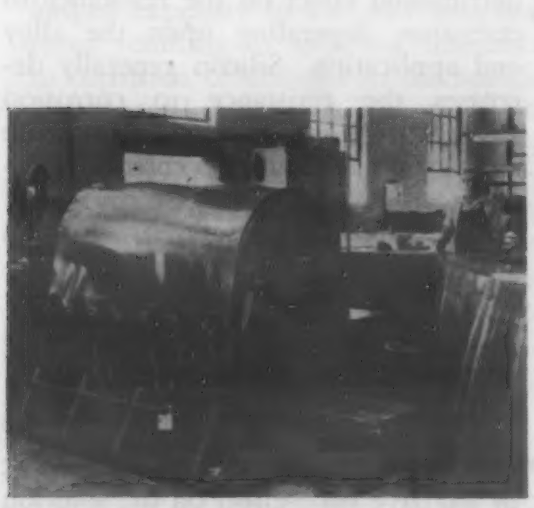
The high-purity alloys, such as 99.5% aluminum, have a solution potential of −0.84 v. measured against a standard 1/10th normal calomel electrode in a solution containing 57 grams of sodium chloride and 0.3% hydrogen peroxide. The amounts of the impurities iron and silicon, present in 2S, have little effect on the solution potential, decreasing the negative voltage only a minute amount. The alloy 3S has the same solution potential as 2S even though it normally contains

1.25% manganese. Most of this is present in the form of the insoluble constituent $MnAl_6$ which is reported to have a solution potential of −0.85. The alloy 52S which contains small amounts of copper, iron and silicon and 2.5% (nominal) magnesium is more anodic than pure aluminum.

All of the magnesium in 52S does not stay in solid solution but forms the constituent Mg_5Al_8 which has a solution potential of −1.07 v. This finely dispersed precipitate, being more anodic, will be subject to galvanic attack, but the severity of attack is naturally minute.

From the above it can easily be seen why high-purity aluminum, and the common alloys such as 2S, 3S and 52S are generally subject only to the general pitting type of corrosion. The story for the heat-treatable alloys, however, is entirely different. As previously stated, the strong alloys are those which contain elements, groups of elements or constituents that have considerable solid solubility at elevated temperatures and limited solid solubility at lower temperatures. Galvanic action, and therefore corrosion, of this type of alloy can perhaps be best explained by the following example:

The alloy 24S nominally contains 4.6% copper, 1.6% magnesium and 0.60% manganese, with minor amounts of iron and silicon as impurities. The iron is present as the insoluble constituent Al-Cu-Fe-Mn. Silicon is present as Mg_2Si which is *insoluble in 24S* at the heat-treating temperatures employed. The remaining manganese is present as a dispersoid. The soluble constituents are Al-Cu-Mg and $CuAl_2$, with the Al-Cu-Mg constituent being predominant in the wrought structure.



One of the common methods of forming aluminum is by stretching. Here 0.051-in. sheet R301-O is being stretch formed.

To obtain the high strength normal for 24S, the alloy is subjected to a solution heat-treatment and allowed to age-harden. The solution heat-treatment consists of bringing the alloy quickly up to a predetermined temperature, which for 24S is 925 to 930 F, holding at this temperature a sufficient length of time to allow substantially all of the soluble constituents to go into solid solution and then rapidly quenching to prevent (in the case of 24S to retard) precipitation from the then supersaturated solid solution or solutions.

The alloys 17S and 24S contain enough *effective* magnesium and copper to cause natural precipitation or aging to take place; the other commonly employed heat-treatable alloys must be artificially aged at moderately elevated temperatures to obtain maximum strength. With 17S and 24S the rapid quench from the solution heat-treating temperature merely delays the decomposition of the solid solution, with precipitation starting almost immediately after quenching and being substantially complete after 48 hr.

The precipitation, in correctly heat-treated 17S-T and 24S-T, while being general throughout the grains, is more pronounced along certain crystallographic planes and along the grain boundaries. The precipitates, which are the constituent $CuAl_2$ and/or Al-Cu-Mg or slight modifications thereof, are much more cathodic than both the solid solution from which they were precipitated and the resulting impoverished or depleted zones surrounding the precipitate. The constituent $CuAl_2$, for example, has been reported as having a solution potential of −0.53 v. As a result, the resistance to corrosion of the high copper-bearing alloys is less than that possessed by many of the nonheat-treatable alloys. In addition, the oxide films on these alloys are not as resistant to penetration as those formed on the common alloys.

When 24S, or any high copper-bearing heat-treatable alloy, is subjected to an improper quench, the size and severity of the excessive precipitation formed along the grain boundaries and certain crystallographic planes *and* the impoverished or depleted zones adjacent to these boundaries and planes may be such that the alloy becomes susceptible to a serious preferential galvanic attack known as *intergranular corrosion.*

When intergranular corrosion occurs, the impoverished zones adjacent to the grain boundaries, being anodic to both the matrix and the precipitate, are attacked. This attack quickly penetrates the metal resulting in a serious loss of mechanical properties. This type of attack is known as *interfragmentary corrosion* when present in an unrecrystallized structure, which is often predominate in large extruded sections.

The main factors which cause a high copper-bearing alloy to become susceptible to intergranular attack are a slow quenching rate, a delayed quench and, with some alloys, heating to critical temperatures after quenching. Most of these alloys are solution heat-treated at temperatures near the melting point of their lower melting constituents to put substantially all of the soluble constituents in solution. Unless the quench is rapid, the metal cools and preferential precipitation will be excessive. Slow quenching, such as air, oil, and warm or hot water quenching, definitely promotes preferential precipitation. Prolonged heating above 250 F after quenching also promotes preferential precipitation in many of these high copper-bearing alloys.

The clad alloys obtain their high resistance to corrosion by galvanic protection. The cladding is so chosen that it is more electronegative than the core material and will be subject to attack first. The cladding material is also generally either high-purity aluminum or an alloy that is substantially a solid solution, to insure a general pitting type of corrosive attack. Thus the core material will not be attacked until the cladding has been substantially removed even though relatively large areas of unprotected core material may be exposed to the corrosive attack.

The high copper-bearing alloys, such as 14S, 17S and 24S, should never be used in the *annealed temper* because of their inferior resistance to corrosion in this temper. The alloy 24S-O, for example, seldom has more than 0.4% copper in solid solution, the remainder being out of solution in the form of the various constituents. The resulting microstructure is such that these alloys, in the annealed condition, are very susceptible to galvanic corrosion.

A few of the very high strength alloys, particularly the high zinc-bearing alloys, are occasionally susceptible to what is known as stress-corrosion cracking which is the fracture of metal under the combined effect of high

stress and corrosion. In aluminum alloys, this type of attack has been proven to be the result of preferential galvanic attack, generally along grain boundaries. The use of small amounts of specific elements and the control of the precipitation processes has alleviated this difficulty and these alloys can be successfully employed for most applications.

It is suggested that complete technical data be obtained when contemplating the use of the high zinc-bearing alloys or artificially aged 24S under extremely severe corrosive conditions in conjunction with exceptionally high continued stresses.

High-purity aluminum should be used when maximum resistance to corrosion is imperative. The alloy 2S is widely used because of its superior resistance to corrosion; alloy 3S has practically the same resistance as 2S when exposed to the atmospheric or to saline solutions. The alloy 52S is more resistant to corrosive attack than 2S when exposed to saline solutions.

The alloys 53S and R353 are the most corrosion resistant of the heat-treatable alloys, being practically equal to 2S except under some forms of chemical attack. The alloys 61S and R361 are less resistant to saline attack, but are otherwise about equal to 53S and R353. Unprotected 17S and 24S are inferior to R361 but are resistant materials. Properly produced clad alloys are highly resistant, being as resistant as their claddings.

The clad alloy R301 is as resistant to corrosion as R361. Unprotected R303 is superior to bare 24S-T. Clad R303 is comparable to Pureclad 24S-T (clad with high-purity aluminum).

Chemical Resistance

A desirable property of aluminum and its alloys is resistance to attack from many chemicals and foods. Even when they are slightly attacked the aluminum compounds formed by such attack are colorless and non toxic.

There are many chemicals that severely attack aluminum. However, the use of suitable inhibitors, such as sodium silicate or sodium chromate, permits the use of aluminum with many of these materials.

Many strong mineral acids, alkalies and acid-salt solutions quickly penetrate the oxide film and attack aluminum, forming a salt and liberating hydrogen. Unprotected aluminum alloys should not be used with such solutions.

Concentrated nitric acid (95% by weight) does not attack high-purity aluminum, 2S or 3S. The rate of attack at concentrations above 80% or below 5% is very slow, but the attack is generally considered excessive for concentrations between 5% and 70% by weight.

The attack by sulphuric acid is somewhat greater than with nitric acid although high-purity aluminum, 2S and 3S are used in solutions containing as much as 5% sulphuric acids. The high-purity alloys have been successfully used with 15% solutions, by employing the Alrok process to increase the thickness of the oxide film, although such use is not generally recommended. Fuming sulphuric acid has a low rate of attack, but any appreciable amount of water or water vapor causes serious attack. Concentrations between 15% and 110% (by weight) are very corrosive to aluminum.

Hydrochloric, hydrofluoric and hydrobromic acid solutions readily attack the aluminum alloys. In fact, very dilute solutions of hydrofluoric acid are used to clean and etch aluminum surfaces.

Perchloric acid is decidedly corrosive to aluminum alloys. Phosphoric acid solutions are used to clean and etch aluminum surfaces and, therefore, should not be in constant contact with aluminum.

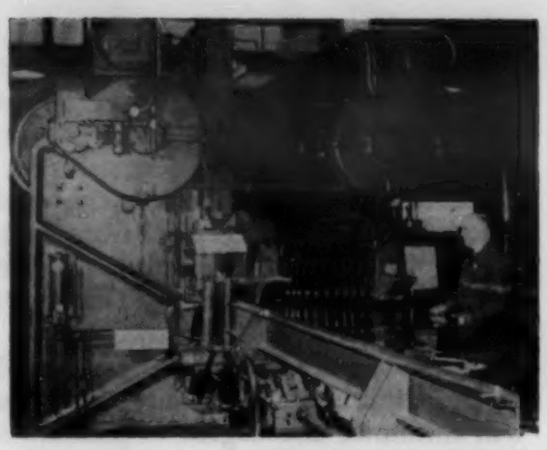
All strengths of boric acid solutions have very limited effect on aluminum. Weak solutions (less than 5%) of chromic acid have little effect on aluminum but the rate of attack is excessive for concentrations over 10%.

Simple organic acids, such as acetic, citric, lactic and tartaric acids, *in conjunction* with a slight amount of water, have little or no effect on aluminum. The fatty acids, such as stearic acid, likewise have a low rate of attack. However, unless a fraction of a per cent of water is present the attack may be pronounced. Uncontaminated fruit acids generally do not attack aluminum. The addition of sugar reduces the attack of pineapple juice.

Simple acids that contain a halogen radical, and such acids as formic and oxalic acids are too corrosive for most applications.

Strong caustic solutions rapidly attack aluminum. Weak solutions, containing chemical inhibitors have a low rate of attack and can be satisfactorily used, if certain precautions are taken.

Ammoniacal solutions have little effect on aluminum after building up a protective surface film. Calcium hydroxide and calcium chloride, in the presence of water, are highly corrosive to aluminum unless a corrosion inhibitor is used.



Aluminum alloy sheet is cut to precise dimensions by means of huge shears such as this.

Salts composed of strong acid radicals (except the halogens) and weak base radicals usually have very little effect on aluminum. The halogen-bearing salts, such as ammonium chloride, are very corrosive unless used in conjunction with an inhibitor. Ammonium nitrate and ammonium sulphate can be satisfactorily handled with aluminum.

Salts composed of weak acid radicals and strong base radicals, which hydrolyze forming pseudo-alkaline solutions, should not be used with aluminum unless suitable corrosion inhibitors, such as sodium or potassium chromate or sodium silicate, are employed. High magnesium-bearing alloys, such as 56S, stand up best under this type of attack, while 3S is superior to 2S.

Neutral salts, and solutions of neutral salts, have little effect on aluminum if heavy-metal salts are absent. However, solutions containing strong halogen salts are corrosive to aluminum, especially when heavy metal salts are present, unless a corrosion inhibitor is employed. Neutral nitrates and sulphates are not corrosive to aluminum. In fact, the nitrates are mild inhibitors of corrosion.

When aqueous solutions or liquids containing small amounts of water, contaminated with heavy metals or their salts, come in contact with aluminum, a severe pitting type of corrosion may occur. Aluminum being

anodic (electronegative) to practically all of the heavy metals will replace them from their compounds. The replaced metals will be deposited upon the aluminum surface causing galvanic action to occur. This attack is concentrated, forming surface pits. Eventually the small pits become holes and the aluminum must be replaced. This type of corrosion is naturally slow and can be controlled by the addition of corrosion inhibitors. Frequent cleaning will minimize the degree of attack.

Care must be exercised when making blanket predictions of the behavior of the aluminum alloys to all types of corrosive conditions. For example, impure sodium or calcium chloride brines, which ordinarily attack aluminum, have no appreciable effect when inhibited with sodium chromate (1% of the chloride content). On the other hand, acetic acid, which normally does not affect aluminum, can cause serious attack if contaminated with heavy metal salts.

It should be specifically understood that the information and general rules listed herein, while correct for most applications, should not be construed as covering all conditions of exposure. For example, carbon tetrachloride does not attack aluminum. However, the addition of a small amount of water may cause serious attack, due to the formation of hydrochloric acid. The possibility of such reactions should be fully investigated.

Atmospheric corrosion of aluminum and its alloys is generally not excessive. When used under severe conditions it is advisable to use a common alloy, a magnesium-silicide type alloy, a clad high-copper or zinc-bearing alloy or to employ some added protection such as paint or one of the electro-chemical finishes given in the section as finishing.

Forming and Drawing Characteristics

It has been said that aluminum is the most easily worked structural metal, being readily fabricated by every commercially used process. There are, however, several characteristics which must be considered to enable one to realize this asset to the fullest extent.

Aluminum has excellent cold formability, its crystalline structure being the face-centered cubic type, in common with most of the ductile metals. When selecting an alloy, an index of the formability can be obtained from the tensile strength, the yield strength and the per cent elongation. The higher tensile and yield strengths require more power for forming. The alloys that possess a wide range between the tensile and yield strengths generally have a larger capacity for cold work than those with a narrow range. The alloys possessing high elongation values can usually be given deeper draws than those with low elongations. However, care should be exercised when judging an alloy solely on the per cent elongation as there are many drawing operations where an increase in the tensile strength is more important. As an example, 2S-½H, with a minimum guaranteed elongation of 7% in 2 in. will generally take a deeper draw than 2S-¼H with a minimum elongation of 10% in 2 in., simply because it possesses slightly higher tensile and yield strengths.

Another factor which must be taken into consideration is the rate of strain-hardening. As a general rule, increasing the amount of alloying elements increases the rate of strain-hardening. The alloy 52S, for example, requires the use of more power and less reduction-per-draw than does 2S or 3S.

Forming and drawing are often considered synonymous terms. In the aluminum industry, however, the term *forming* is generally used to indicate a change in shape without any appreciable change in the thickness of the material. Since there is no change in cross-sectional area, the material is not severely work-hardened and usually does not require an anneal.

The term *drawing* is associated with a working operation which incorporates a substantial reduction in the cross-sectional area of the material. During the operation the material work-hardens, increasing the mechanical properties and decreasing the workability. The reductions per draw must, therefore, be successively decreased for the first few draws.

One very important factor to take into consideration when forming and drawing aluminum alloys is the minimum radii used. The use of suitable radii cannot be overstressed. Usually more liberal radii are required than are necessary for steel.

The choice of alloy often depends upon the minimum radius required in the forming and drawing procedures. In Table VI the various alloys and tempers are listed in groups of increasing minimum radii required for 90 deg. cold bends. The *positions in* each group are purely relative and are subject to wide variations depending upon such factors as analysis, forming operation, design and condition of the dies, etc. In addition, the mechanical property ranges of the intermediate tempers of the common alloys overlap, which means that it is possible to have material that can be correctly placed in two temper classifications.

It is difficult to formulate definite rules for predicting the drawability of the alloys since this is dependent upon the type of operation. It is impossible to predict the minimum bend radii for a particular alloy or the strongest material applicable for a definite radius. The only way to accurately determine this is by actual trial.

One common error in selecting an alloy is to choose a stronger temper of the same alloy when additional strength is required from a nonheat-treatable alloy. As an example, if 2S-½H has satisfactory drawing properties but does not possess sufficient strength, the additional required strength can be obtained by using 3S-½H which has substantially the same formability. The use of 2S-¾H, while perhaps supplying additional strength, may not be suitable due to decreased formability.

Often many factors must be considered when selecting an alloy. As an illustration, let us assume that we wish to select an alloy for the production of a variety of pots and pans. The heat-treatable alloys can be ruled out as being more expensive. The choice now lies between high-purity, 2S, 3S and 52S. High-purity material is more expensive and is too soft. The alloy 52S is the strongest but is also more expensive and may have insufficient drawability to produce drastically formed and drawn articles. The choice therefore lies between the various tempers of 2S and 3S. If the draws are slight, perhaps either alloy in the ½H temper will be satisfactory. If the total amount of working is high, the an-

TABLE VI **Minimum Recommended Radii for 90-deg. Bend**
(In groups of Increasing radii)

A	High-Purity Aluminum, 2S-O, 3S-O, R353-O, 53-O, 52S-O
B	R361-O, 61S-O, R301-O, 17S-O, Pureclad 24S-O, 24S-O, R303-O, R301-FQ, 24S-FQ, 2S-¼H, 3S-¼H, 2S-½H
C	3S-½H, 52S-¼H
D	2S-¾H, 52S-½H
E	R361-W, 61S-W, 3S-¾H
F	R353-W, 53S-W, R361-T, 61S-T, A17S-T, 52S-¾H, 2S-H
G	R353-T, 53S-T, 3S-H, 52S-H
H	R301-W, 17S-T
J	R301-T, Pureclad 24S-T, 24S-T, R303-T315, R303-T275
K	Pureclad 24S-RT, 24S-RT, Pureclad 24S-T81, Pureclad 24S-T86

Minimum Recommended Radii in Terms of Thickness for 90-deg. Cold Bends

Group Classification	Gage up to 0.065	Gage 0.065 to 0.129	Gage 0.129 to 0.250
A	0	0	0
B	0	0	0 - 1t
C	0	0 - 1t	½t - 1½t
D	0 - 1t	½t - 1½t	1t - 3t
E	0 - 1½t	½t - 2t	1t - 4t
F	0 - 2t	1t - 3t	2t - 4t
G	½t - 3t	1½t - 4t	3t - 6t
H	1t - 4t	2t - 5t	3t - 6t
J	1½t - 5t	3t - 6t	4t - 7t
K	2t - 5t	3t - 6t	5t - 7t

nealed ("O") temper may have to be employed. If this is the case, the additional strength of 3S-O may be vitally important in reducing the number of draws required. Even if 2S-O can be successfully used, the unworked portion of the metal may be so soft that its use is undesirable. Another possibility is that 2S-¼H or 2S-½H may be satisfactory in the drawing operations but will be unsatisfactory when producing a bead around the lip of the article. Thus it appears that a logical choice of alloy would be 3S-O.

Another application for aluminum is the production of beer barrels. The alloy used must possess an excellent resistance to corrosion, high strength, good weldability and formability. Clad products cannot be used as the barrels are cleaned with a hot caustic solution which removes a slight amount of the aluminum. The strength requirements demands the use of a heat-treatable alloy. The resistance to corrosion and to chemical attack requirements are met best by the magnesium-silicide type alloys. The alloy R353 (or 53S) has superior weldability as well as meeting all of the other requirements and is the logical choice.

The aluminum alloys are easily worked at elevated temperatures. Practically all hot forming, however, is confined to forgings and similar commodities. With products such as sheet, tubing and extrusions the hot forming operations are so expensive that they are avoided except for special applications. An important exception is the use of heat when stretcher forming. By this method the aircraft industry has been very successful in producing many difficult shapes with the high strength alloys.

Heating to temperatures less than 650 F does no harm to the annealed temper of any alloy. The strain-hardened tempers, of course, lose some of their strength when exposed to elevated temperatures. Exposure of the magnesium-silicide type heat-treated alloys to high temperatures can cause a slight loss in mechanical properties but does not appreciably affect resistance to corrosion.

Exposure of the high copper-bearing heat-treatable alloys in the "W" (heat-treated) or "T" (heat-treated and aged) condition may cause excessive preferential precipitation to occur. When this happens the mechanical properties are generally impaired and the alloys become susceptible to serious intergranular corrosive attack.

It is often necessary to do a small amount of hand straightening or forming with aluminum alloys. This can easily be accomplished with power hammers, or by employing rawhide mallets.

When forming and drawing operations are performed, the property called springback is often encountered with alloys that possess high yield strengths. This can be corrected by reducing the radius of the punch or by overbending the product. There is no way of predicting the amount of springback which must be determined by trial and error.

One of aluminum's important properties is its forging characteristics. Several of the alloys which possess excellent mechanical properties, resistance to corrosion, machinability and forging characteristics are widely used in forgings. The commonly employed alloys, in groups of decreasing forgeability, are:

- A: A51S, 70S, 25S
- B: 18S, R353, 53S, 32S
- C: 17S, R317, 14S, R303

Again, the listing is relative since

the position in each group depends upon the type and kind of article, and the forging equipment and conditions.

Alloy 18S is used where good performance at moderately elevated temperature is required, with alloy 32S being employed when a very low coefficient of expansion is an additional requirement. Alloy R353 (or 53S) is easily forged, and possesses moderately high mechanical properties. Alloy A51S is of moderate strength and possesses exceptional forging characteristics. Its resistance to corrosion is good, being superior to 17S. The mechanical properties of R353 are slightly less than A51S but it offers excellent resistance to corrosion and good weldability.

The alloys R303 and 75S are used where extremely high mechanical properties are required. Their resistance to corrosion is good. The alloy 14S offers high strength with relatively good forgeability with a resistance to corrosion comparable to 17S. The alloy 17S is weaker than 14S but offers better machinability. The alloys R317 and 11S are employed when maximum machinability is required.

It is sometimes difficult to ascertain the feasibility of using forgings for a particular application. Many articles can be rapidly produced with smooth surfaces and close tolerances. Costs may be lower or higher depending upon the number desired, the dimensions and similar factors. In cases where the cost of a forging is higher, the assembly costs may be such as to make its use economical.

Pure aluminum and several of the *common* alloys readily lend themselves to the impact extrusion process for the production of thin-walled symmetrically shaped containers for use in packaging cosmetics and similar products.

Blanking, piercing and perforating operations are easily performed with aluminum alloys. When blanking, the clearance between the punch and die should be such that approximately 1/3 the thickness of the metal is cut with the rest being sheared. As a general rule, the diameter clearance should be from 2/10 to 3/10 the sheet thickness, depending upon the thickness and temper of the sheet. Lubrication should be generous. Excellent results can be obtained by using medium engine oil which contains small quantities of kerosene and a fatty oil. It may be necessary to increase the kerosene content for use with the stronger alloys.

Some of the common or nonheat-treatable alloys, such as the high-purity alloys, 2S and 3S, are easily spun. The high-purity alloys and 2S do not require an intermediate anneal. The alloys 3S and 52S require more breakdowns and an anneal on deep forming operations.

Aluminum and its alloys are successfully employed for applications such as stamping, embossing and coining. The appearance of the products can be exalted by the application of one of the many finishes suitable for aluminum. The selection of the alloy will depend upon the strength and hardness required. The alloy and temper chosen should possess, for best results, a high per cent elongation and a low ratio of yield to tensile strength.

Machining Behavior

Most of the wrought aluminum alloys possess excellent machining characteristics. These characteristics are, however, different than those for copper, brass or steel. For optimum results, it is necessary to acquire tool set-ups to take full advantage of the free machining qualities. Under ideal conditions, the free-machining aluminum alloys will machine 10 times faster than steel. Usually the rate of machining is limited only by the available equipment.

There are a few general rules to remember when machining the aluminum alloys. Tools should be ground so that a slicing action is obtained, with considerably more side and top rake being necessary for aluminum than for steel. Clearance should be enough to prevent rubbing, but too large a clearance will cause chattering. A clearance of 7- to 10-deg. will generally be found satisfactory.

Carbide-tipped or high-speed steel tools are recommended for production work although plain carbon steel tools can be used. Regardless of the type of tool, the cutting edge must be kept free of scratches and burrs. A generous supply of cutting coolant is necessary.

Aluminum alloys should be machined at much higher speeds than are used for steel. Medium to fine feeds should be used when a smooth surface is required, as heavy feeds increase the heat formation, causing poorer work. For most lathe work, a round-nosed tool having a 40- to 50-deg. top rake with 8- to 10-deg. clearance, set on or slightly above the work center will perform satisfactory. A side rake of 10- to 20-deg. produces a smoother surface. An elliptical-nose tool with a top rake of 20-deg. and a side clearance of 10-deg. is generally satisfactory for removing a large amount of stock.

Parting tools should have a top rake of 15- to 20-deg. with 4- to 5-deg. side clearance.

Boring tools should be of the "hook" type, having from 25- to 50-deg. top rake, 10- to 15-deg. side rake and enough clearance to prevent the lower tool surface from dragging on the work during the cutting operation.

Milling operations on aluminum and its alloys should be performed at high tool speeds to prevent gumming. A cutter speed of ,000 r.p.m. is satisfactory. Twenty-five degree spiral milling cutters with coarse teeth (enough to give a 0.008 in. chip), plenty of chip room and up to 20-deg. top rake are preferred. The flutes should be highly polished. Fast feeds should be used, with speeds up to 60 in. per min. being employed.

Planer and shaper tools for roughing cuts should have a top rake of 12- to 15-deg., a side rake of 32- to 38-deg., and front and side clearances of 8- to 10-deg. Finishing tools should have from 45- to 50-deg. top rake, 50- to 60-deg. side rake, 8- to 10-deg. front clearance and little or no side clearance. A fine feed should be used for finishing cuts with means supplied to prevent the tool from contacting the work on the back stroke.

Twist drills should have larger spiral angles than standard, highly polished deep flutes, narrow lands, more lip clearance (up to 18 deg.) and thinner points than standard. They should operate at peripheral speeds of 500 to 600 ft. per min.

Threading taps should have highly

polished flutes and should be undercut. The rake angles should be increased to 12 to 18 deg. Spiral flutes will provide better chip clearance and minimizing tearing. Tapered taps perform more efficiently and produce a cleaner thread if the relief is slightly reduced.

Coarse-teeth circular saws should have a 15-deg. side rake, 35- to 45-deg. top rake and twice the clearance used for steel, providing a positive feed is employed. For hand feeds, the top rake angles should be reduced to 2- to 5-deg. Better chip breakage can be obtained, on positive feed equipment, if the teeth are designed to cut alternately high and wide.

There are many excellent commercial cutting compounds designed specifically for use in aluminum machining operations. In addition, the soluble-oil emulsions, kerosene and kerosene-lard oil mixtures are satisfactory for most turning, shaping, planing, sawing, drilling and grinding work. High viscosity cutting lubricants are recommended for tapping operations.

Methods of Joining

Riveting

The most commonly employed method of joining aluminum is riveting as this method has the widest latitude of application and is far more flexible than any other method of assembly.

A variety of forms of rivets are available, including such types as champered shanks, tubular, semitubular and explosive rivets. Each type is available with a number of different types of heads, including the round, flat, countersunk and brazier types.

Rivet holes can be produced by drilling, punching or reaming. The diameter of holes should be such to insure a close fit. As a rule 0.010 in. total clearance will be sufficient.

As the rivets are driven, the metal in the shank is upset forming an additional head. The rivets should be driven with a few well placed strokes to produce optimum results. Better results are usually obtained by applying the blows to the already formed head.

Blind rivets are used when one side of the work is inaccessible. The most popular types are explosive rivets, which are detonated by heat, Goodrich Rivnuts and cherry rivets.

Rivets are produced in the following alloys: 2S, 3S, 17S, A17S, 24S, R353, 53S, and 56S. The choice of alloy is dependent upon many factors. Whenever practicable it is desirable to use rivets of the same alloy as the metal being joined, with the alloys 2S and 3S being used for riveting most of the common alloys. The alloy 52S should be joined with R353 or 53S rivets. The heat-treatable high copper-bearing alloys can be joined with 2S, 17S and A17S rivets. Pureclad 24S should preferably be joined with 53S or R353 rivets because of excellent resistance to corrosion. Magnesium alloys should be joined with 56S rivets.

Rivets of 2S, 3S and 56S are driven cold. Rivets of R353 in the "W" and "T" and A17S-T can also be driven cold. Rivets made from 17S and 24S, must be heat-treated and, to minimize natural aging, kept at a temperature of 32 F or below until they are used.

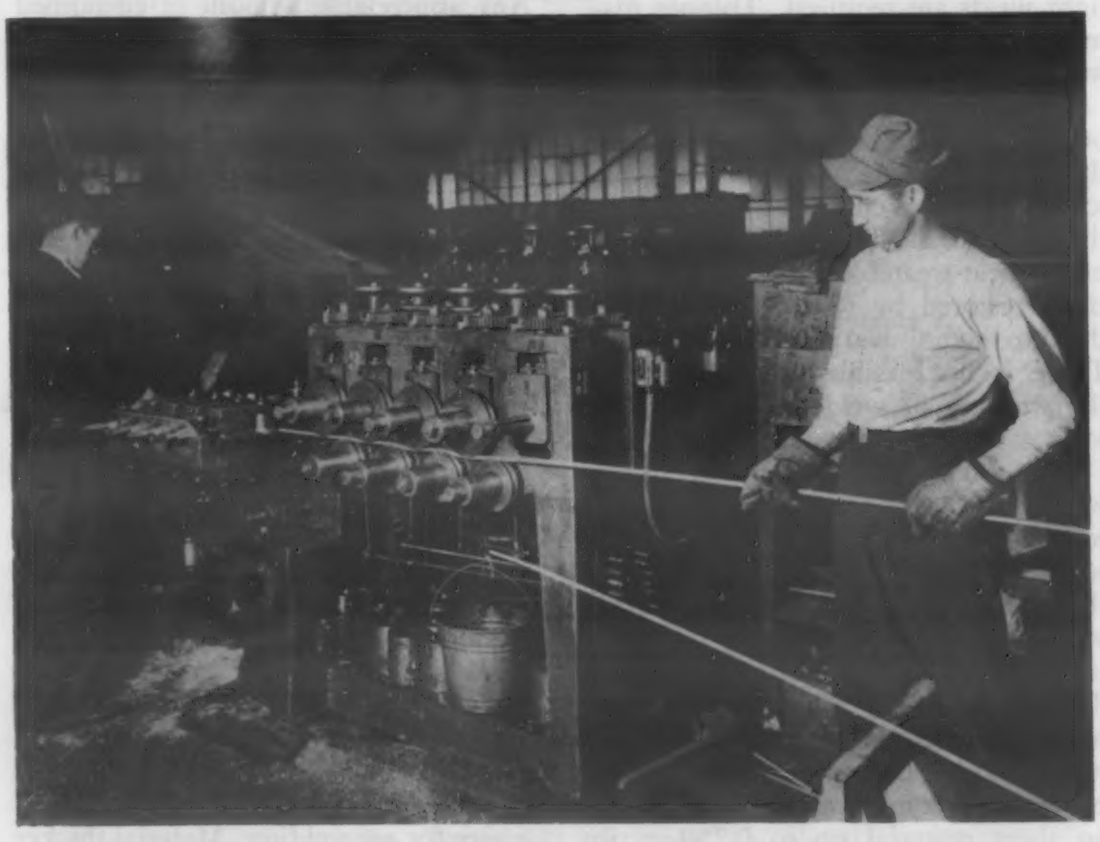
Welding in General

Practically every form and type of welding known has been tried on aluminum, with varying degrees of success. However, the fact that a sound-appearing weld can be produced by a certain method does not necessarily imply that its use is desirable.

All of the aluminum alloys can be satisfactorily joined by spot welding. In cases where corrosion is severe it is usually advisable to use a cladded sheet product if an exceptionally strong alloy is desired.

The push and flash types of welds are inferior to spot welding when employing the high copper-bearing alloys because of their impaired resistance to corrosion. Seam welding is, of course, a special type of spot welding.

Gas welding and arc welding are recommended for high-purity, 2S, 3S, R353 and 53S, R361 and 61S, and 52S in the order given. It should be kept in mind that the welds in R353 and R361 will not have the strength of the parent material, even after heat-treatment, due to the as-cast structure



Rod stock is straightened by means of a roll straightening machine.

of the weld. Their resistance to corrosion is only slightly impaired. The tempers of the common alloys will also lose strength due to the annealing effect of the flame. Some difficulty may be encountered with 52S, due to cracking, although this can be minimized by special welding practices. The high copper-bearing alloys can be successfully joined by these methods but their strengths and resistance to corrosion are greatly impaired. Distortion may be excessive and heat-treatment is usually a necessity. Regardless of these limitations, the high copper-bearing alloys are successfully being welded for many applications.

The aluminum alloys become extremely plastic when heated to high temperatures. As the temperature approaches the melting point of the lower-melting constituents, the percentage elongation drops until it is practically nil. It is therefore imperative that the metal remain free from stress during this period.

The oxide film that is always present on the aluminum alloys must be removed before a sound weld can be made. This can be accomplished by the use of a flux or in the case of restance welding, by mechanical means.

Gas Welding

Gas welding, including such types as oxy-hydrogen and oxy-acetylene, is applicable to materials 0.032-in. or over in thickness, particularly if gas-tight welds are required. Thinner materials should be resistance or seam welded.

Gas-welded joints of strain-hardened or heat-treated material will not have the strength of the parent material due to the annealing effect of the flame and the structure of the weld. The strengths of the heat-treatable alloys can be partially restored by reheat-treatment although some warping may occur. There is no feasible way to increase the strength of welded "common" alloys.

The edges of the material to be welded are prepared somewhat similar to steel. No edge preparation is necessary for thickness up to 0.051-in. when the material is joined with a butt-type weld. Sheet material up to 0.125-in. in thickness can be joined with a flange-type weld. With this method of welding the flange is melted down with little or no welding rod used. Unbeveled butt-type welds can be made on sheet material up to 0.250-in. in thickness although it is advisable to notch the heavier gages with a saw or chisel to facilitate full weld penetration. Material of over 0.250-in. thickness should be beveled.

Thick material should be preheated to a temperature of 500 to 700 F to prevent cracking and reduce gas consumption due to the high thermal conductivity of aluminum. Thin sections should be warmed to prevent cracking.

The greatest difficulty a welder, inexperienced in aluminum, has to overcome is the failure of the deposited metal to adhere to the base material. This is attributed to the use of an improper base temperature. To correctly produce a satisfactory weld the base material, protected by flux, or an inert gas, must be in a molten condition at the time the molten filler rod is introduced. The welding flame should be neutral.

The alloys 2S, 3S and the high-purity alloys should be welded with 2S wire. The alloys A51S, 52S, R353, 53S, R361 and 61S should be welded with 43S wire. The alloys 75S and R303 should be welded with similar material as 2S and 43S are not suitable. R301 may be welded with 43S or thin strips of the parent material.

Too much cannot be said regarding the correct use of the proper flux. The flux is so prepared that the oxides are removed by chemically combining with it. The copious use of flux will retard the oxidation of the molten metal and will dissolve the oxides that do form. Any appreciable amount of entrapped oxide will cause a weld to be defective.

The fluxes used are extremely corrosive to aluminum and must be removed immediately. This can be accomplished by boiling water, steam or by immersing in a cold dilute nitric acid or a warm 5% sulphuric acid solution.

Arc Welding

Aluminum lends itself readily to the various forms of arc welding, employing both a.c. and d.c. machines. By far the most popular form of arc welding is the metal-arc process. This type of welding concentrates the heat in a limited area, thereby preventing excessive expansion and minimizing distortion. Material thinner than 0.040 in. is difficult to weld by this process. Where gas-tight joints are required the minimum recommended thickness is 0.187-in.

Very little edge preparation is necessary for arc welding. Material thicker than 0.250 in. should be beveled from 60 to 90 deg. when butt-welding. A backing strip of copper, steel or asbestos, containing a half oval groove, is a prerequisite for a uniform weld surface. The use of heavily flux-coated electrodes is imperative since this helps control the arc. The flux forms a low density slag, stabilizes the arc, prevents excessive oxidation and removes the oxides that are formed. It should be removed by one of the methods already discussed. It is desirable to preheat the heavier gages to a temperature between 250 and 400 F.

A very short arc is necessary, it being desirable to keep the arc length under 3/16-in. The electrode should be the positive pole type. Current requirements are approximately directly proportional to the thickness of the material being welded when the proper size electrode is employed, with 0.125-in. material requiring a current of about 80 amp. When the weld penetration is insufficient the amperage should be increased or the welding speed decreased. An excessively high current or a slow welding speed will burn the material.

The electrode should be the same alloy, or have approximately the same solution potential, as the base material for maximum resistance to corrosion. The alloy 43S (5% silicon) is popular because of its fluidity and can be safely used with the common alloys and many of the heat-treatable alloys. It should not be used with 75S and R303.

Multiarc Welding

A comparatively new method of joining aluminum, which employs two carbon electrodes and one metal electrode, is known as the multiarc welding process. Two sources of current are employed. When properly used 5 individual arcs are produced. The advantage of this method is that a large amount of controlled heat can be concentrated in a small area, allowing the production of a weld of uniform penetration that is relatively free from gas and porosity. With this method, sheet as thin as 0.16-in. has been satisfactorily welded.

While the multiarc welding method possesses advantages over other methods of welding it still retains the basic objections inherent with all fusion welding.

Spot Welding

Spot welding, a form of resistance welding, is applicable to all of the alu-

minum alloys. However, the high thermal and electrical conductivities of these alloys require the use of an extremely high welding current and a very short discharge time.

An electrode pressure of 58,000 p.s.i. before and after welding and 23,000 p.s.i. during the welding process is recommended for general use. The current requirements are between 13,000 and 36,000 amp. depending upon the alloy and the thickness of the material. The discharge times will vary from 4 to 15 cycles, depending upon the thickness of the material.

The protective oxide film should be removed from the surface of the alloys, with the possible exception of 2S, 3S and the high-purity alloys, to prevent electrode pickup and to produce consistent welds. The oxide can be removed with steel wool, emery cloth, rotary wire brushes, hot caustic solution or a number of commercially prepared cleaners.

Seam Welding

Seam welding is the commercial name for a spot welding process applicable to the aluminum alloys. This method uses specially prepared roller electrodes which produce a series of closely spaced independent overlapping spots. By this means, liquid and gas-tight containers can be quickly and economically produced.

Push and Flash Welding

The push and flash methods of welding are quite similar and are often employed when producing butt-welds. When using the push welding method, the pieces of material to be welded are kept in contact under constant pressure. When current is applied, melting occurs at the intersection producing a weld. This method is applicable only to simple cross sections. The flash method of welding is similar to the push method except that the current is applied while the pieces of metal are coming in contact with each other. Melting occurs during the sparking or flashing period, with fusion taking place immediately afterwards. This method of welding is applicable to almost any type of cross-section.

Aluminum Brazing

Aluminum brazing is the commercial name for a joining process which employs a high silicon-bearing low-melting aluminum alloy. The structure to be joined is heated by torch or in a furnace to such a temperature that the

CHARACTERISTICS OF WROUGHT ALLOYS

In this manual the alloys have been discussed according to various qualities and properties. Here the principal characteristics are given for each of the popular alloys. For detailed information, reference should be made to the appropriate division.

Nonheat-Treatable Alloys

High-Purity Aluminum
These alloys are noted for their high conductivities, reflectivity and excellent resistance to corrosion and chemical attack. They have limited strengths.

2S
A general purpose alloy, possessing excellent drawing, forming and welding properties. Excellent resistance to corrosion.

3S
A general purpose alloy—slightly stronger than 2S. Possesses very good drawing, forming and welding properties. Excellent resistance to corrosion.

43S
A lower melting alloy containing an appreciable amount of silicon. Used for welding rod. Modified compositions are used in production of brazing sheet.

52S
A general purpose alloy with medium mechanical properties. Good forming properties. Excellent resistance to corrosion in saline solutions. Welding characteristics inferior to 3S.

56S
Primarily a rivet alloy. Used for joining magnesium. Also used when a high resistance to akaline attack is required.

Heat-Treatable Alloys

11S
Primarily a rod, bar and wire alloy. Possesses excellent machining characteristics with medium high mechanical properties.

14S
A shapes and forging alloy. Extremely high mechanical properties and hardness. Resistance to corrosion comparable to 17S. "W" mechanical properties comparable to 17S-T.

17S
A general purpose high strength alloy. Ages at room temperature. Good formability. Good resistance to most types of corrosion.

R317
17S with additional elements to give improved machinability.

18S
A forging alloy which gives good performance at elevated temperature.

24S
A general purpose alloy. Ages at room temperature. Possesses higher strengths than 17S with comparable workability and resistance to corrosion.

Pureclad 24S
In sheet and plate forms. Combines strength of 24S with resistance to corrosion of high-purity aluminum.

25S
A forging alloy. Good forging properties. Mechanical properties comparable to 17S, but more easily forged. Resistance to corrosion inferior to 17S.

32S
A forging alloy with a low coefficient of expansion and good resistance to corrosion. Good performance at elevated temperatures.

A51S
A forging alloy with excellent forging characteristics. Possesses a higher yield strength than 17S or 25S. Corrosion resistance is comparable to 17S.

R353
A general purpose alloy, possessing medium mechanical properties and very good resistance to corrosion. Good welding characteristics.

R361
A general purpose alloy, possessing medium physical properties. Its forming properties are slightly superior to R353. Very good resistance to corrosion.

R301
A clad sheet and plate product with mechanical properties comparable to 14S and a resistance to corrosion comparable to R361. Good forming characteristics.

R303
A new alloy, possessing exceptionally high mechanical properties and excellent resistance to corrosion. Formability inferior to 24S. Slightly harder to forge than 14S.

low melting alloy, in the form of wire, sheet, or as the cladding of a sheet, melts forming a weld between the parent materials. The process is applicable to the nonheat-treatable alloys and most of the magnesium-silicide type alloys.

This method of joining is relatively inexpensive, strong, can be employed with thin gage material and has little effect on the resistance to corrosion. The strong alloys can be heat-treated after brazing if additional strength is necessary.

Adhesives

The art—for it is an art—of joining aluminum by "gluing" is rapidly becoming popular. By the use of proper adhesives, metal-to-metal bonds having shear strengths as high as 5,500 p.s.i. have been consistently produced.

Most of the adhesives are a combination of synthetic resins and a rubbery constituent. They generally require both heat and pressure to develop their greatest strength, although a few do not require the use of heat.

At present, the materials are expensive and most of them deteriorate after several months storage. In addition, their resistance to heat is limited, precluding their use in many applications.

In spite of the limitations placed on their use, the adhesives are very effective in joining metal-to-metal and metal-to-non-metallic material. Their use, while perhaps not to be stressed, should be given due consideration. It is interesting to note that adhesives were recently picked as being one of the 10 leading wartime Engineering Materials and Methods developments.

Finishes

A very important feature of any product is its appearance. Aluminum's pleasing natural appearance is sufficient for many applications, with its adaptability towards the many commercial finishes producing countless variations.

As previously mentioned under available forms, the sheet products can be furnished in several finishes. For application where the surface brightness of the mill sheet is acceptable it is economically advantageous to use one of the mill finishes.

It is sometimes desirable to supplement the natural beauty of aluminum with an additional finish. The finishes applicable to aluminum and its alloys can be sub-divided into the following broad groups:

(1) *Mechanical Processes* for altering the appearance of the surface. Finishes such as grinding, sandblasting, hammering, tumbling, buffing and coloring, scratchbrushing and satin finishing fall in this classification.

(2) *Inorganic Chemical Finishes.* There are numerous chemical and electro-chemical processes suitable for aluminum. Included in this group are such processes as etching, Alrok coatings, Anodizing, Alzak coating and electroplating. Several are under patent control.

(3) *Organic Finishes.* This classification includes such finishes as lacquers, enamels, varnishes, paints and porcelainized coatings.

The majority of the mechanical finishes decrease the alloys resistances to corrosion because of their abrasive effect on the metal surface. Highly-polished surfaces, however, possess an increased resistance to corrosion. For applications where the continued surface appearance is important it is advisable to use an additional protective treatment.

Most of the chemical and electro-chemical finishes are processes which produce a dense adherent oxide coating on the aluminum surface. The Alrock process employs a hot, weak solution of sodium carbonate. When a denser and harder coating is needed, the anodizing process is employed. This process, which produces an extremely hard surface of aluminum oxide (similar to corundum), is electro-chemical. The aluminum part is made the anode, hence the name, and is placed in an electrolyte such as a dilute solution of sulfuric, chromic, oxalic or boric acid. The type of coating formed depends upon the electrolyte, the temperature, the time and the voltage used. The sulfuric acid process is known as the Alumilite treatment.

Both anodized and Alroked surfaces can be further enhanced by the application of suitable dyes. The colors, generally organic, will fade upon long exposure to sunlight. For color-fast surfaces a treatment employing mineral pigments is required.

The Alzak process is used to produce high specular and diffuse reflector finishes. With this process, surface impurities are removed and a special surface obtained by an electro-chemical treatment in a dilute solution of hydrofluoroboric acid. The surface then receives a hard oxide coating by means of an electro-chemical sulfuric acid treatment. Specular reflectors made by this process have a reflectivity of approximately 85%, the diffuse reflectors a reflectivity of approximately 80%.

Aluminum can be satisfactorily electroplated but the natural oxide film must be removed. Brass, zinc and cadmium can be plated on aluminum directly from cyanide solutions. Chromium, copper and the precious metals are usually deposited on an undercoat of nickel, but can be plated directly on aluminum.

Paint and lacquer finishes are often desirable for aluminum alloys, with the same general rules applicable for other metals being employed. A large variety of attractive finishes are being produced by these methods.

The surface should be freed from oil and dirt by washing or dipping in a solvent cleaner, by vapor degreasing or by one of the many cleaning solutions. For applications under severe corrosive conditions, an Alrok or an anodizing treatment should also be employed.

The organic finishes are commonly applied by brushing, spraying, dipping, or roll coating although almost any method can be employed.

A primer coat should be used for best adherence under severe corrosive conditions. Aluminum paint and zinc chromate are excellent primers for paint and enamel but, of course, aren't suitable for all lacquer finishes. Primers containing lead are not suitable.

Almost any type of paint can be used on aluminum although the materials more commonly employed are synthetic lacquers, synthetic enamels and aluminum paint. The transparent finishes are usually alkyed or methacrylate resins.

The use of aluminum eliminates the necessity of painting, plating or other finishes in many applications, thereby decreasing fabricating practices. Detailed information is available from the major aluminum producers.

NUMBER 106
February, 1946

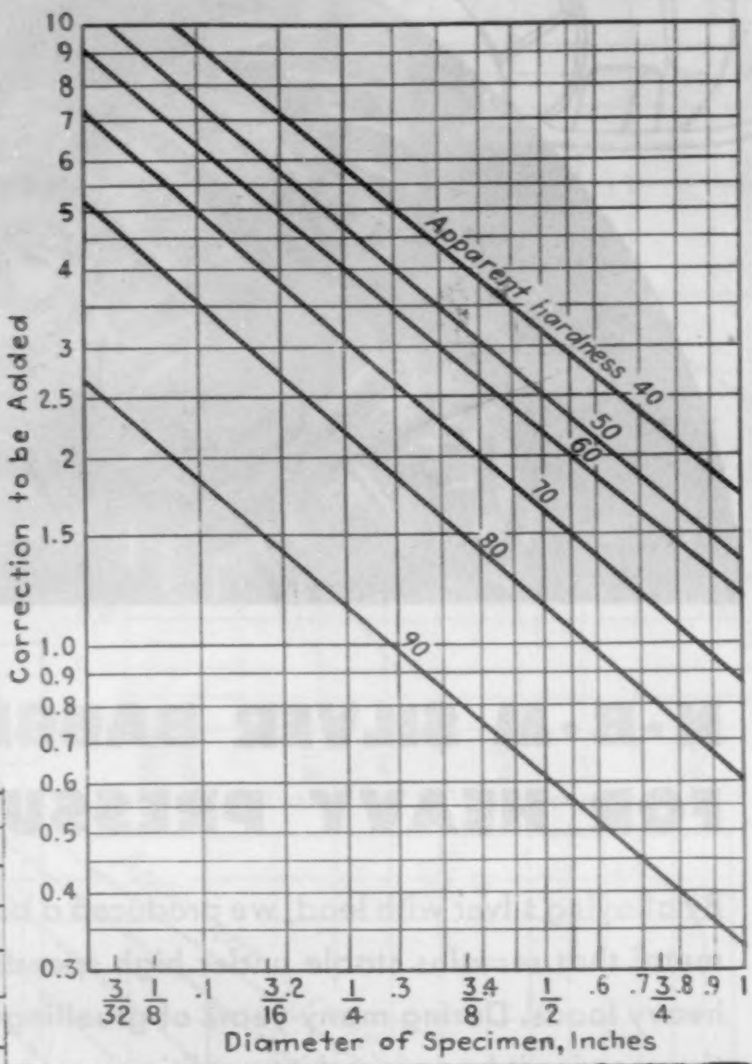
METHODS: Hardness Testing

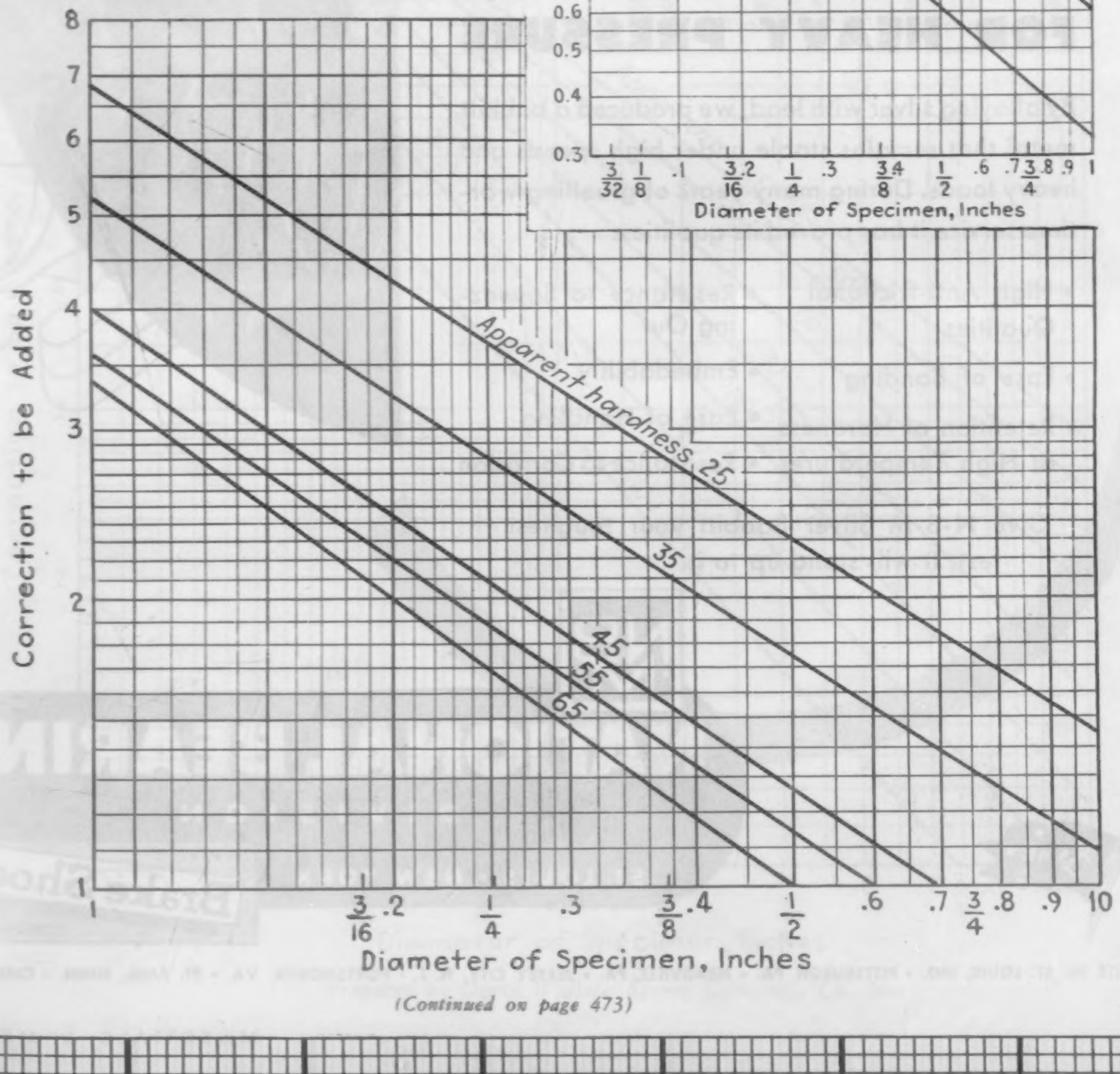
Rockwell Hardness Correction Factors

Rockwell hardness determinations made upon cylindrical surfaces are subject to substantial error unless a correction is made for the curvature of the surface tested. Correction factors are a function of both hardness and diameter.

Correction factors in Rockwell values for both regular and superficial hardnesses were determined empirically and set up in chart form.

The curve on this first page, lower left, shows corrections to be added to Rockwell "C" readings obtained on cylindrical specimens. That in the upper right indicates corrections to be added to Superficial Rockwell "30 T" readings.





(Continued on page 473)

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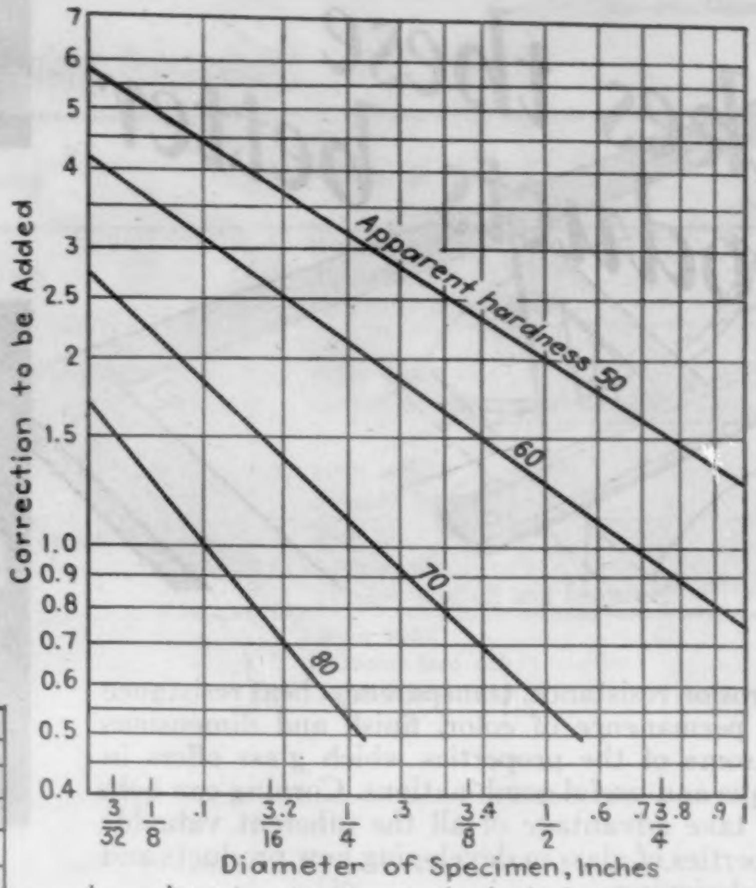
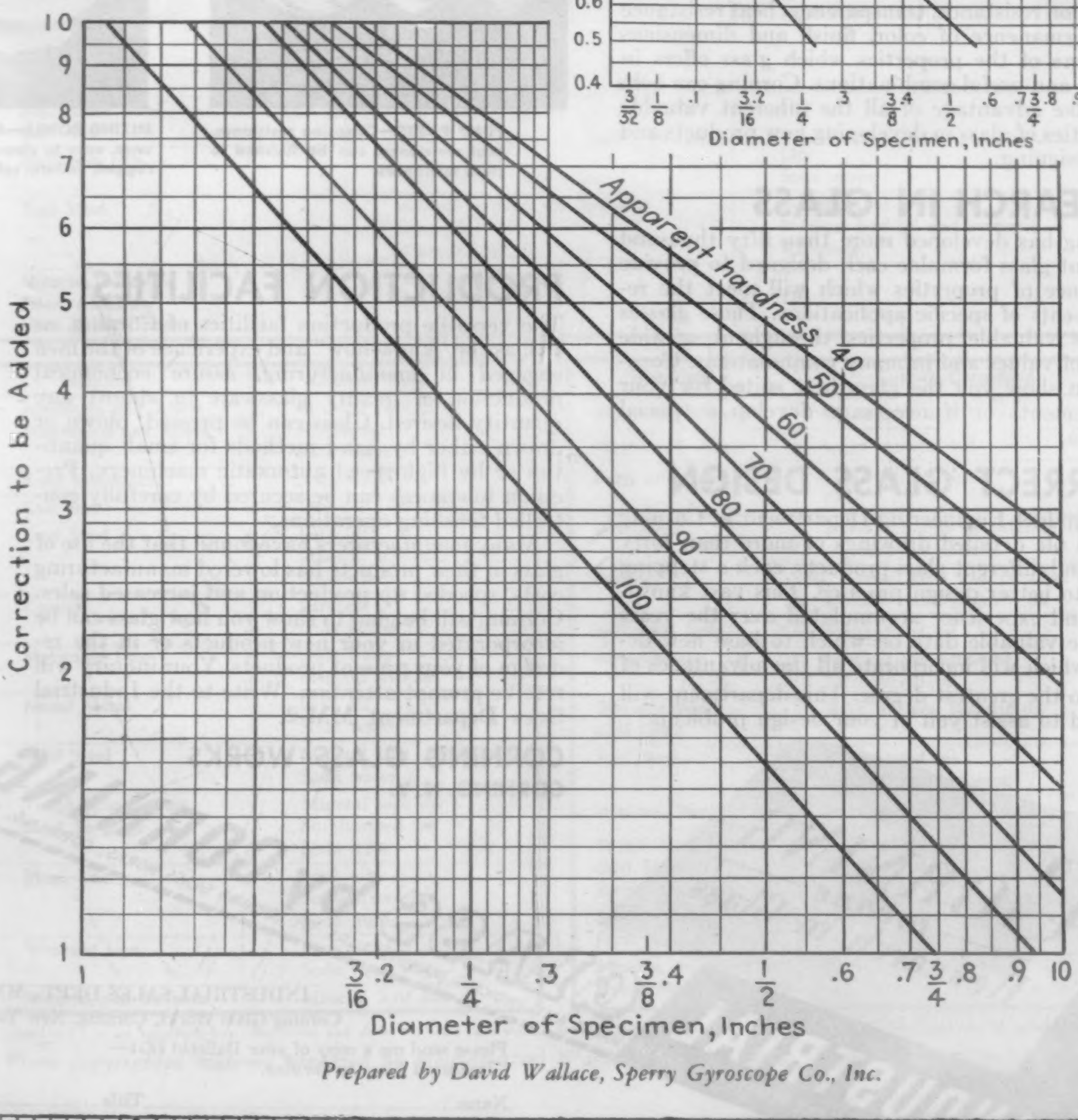
NUMBER 106 (Continued)

Rockwell Hardness Correction Factors

(Continued)

The lower left curve on this page gives corrections to be added to Rockwell "B" readings, while the curve in the upper right shows those to be added to Rockwell "30 N" readings.





Prepared by David Wallace, Sperry Gyroscope Co., Inc.

MATERIALS & METHODS Engineering File Facts

NUMBER 107
February, 1946

Coolants for Machining Operations

DRILLING

Material	Cutting Fluid: Order of Decreasing Effectiveness	Cutting Fluid: Order of Increasing Expense
Aluminum and Alloys	Kerosene Kerosene and lard oil Soda water	Soda water Kerosene Kerosene and lard oil
Brass	Dry Kerosene and mineral lard oil } deep Soda water } holes	Dry Soda water Kerosene and mineral lard oil
Magnesium and Alloys Bronze	Mineral lard oil Soda water Dry	Dry Soda water Mineral lard oil
Copper	Mineral lard oil and kerosene Soda water Dry	Dry Soda water Mineral lard oil and kerosene
Monel Metal Mild Steels Tough Alloy Steels Steel Forgings Cast Steel Wrought Iron	Mineral lard oil Sulphurized oil Soda water	Soda water Mineral lard oil Sulphurized oil
Manganese Steel Cast Iron	Dry	Dry
Malleable Iron	Dry Soda water (deep holes)	Dry Soda water
Tool Steel	Mineral lard oil and kerosene Kerosene Mineral lard oil	Mineral lard oil Mineral lard oil and kerosene Kerosene
Micarta, Bakelite Fiber, Asbestos, Hard Rubber, Ebony	Dry	Dry

REAMING

Material	Cutting Fluid
Aluminum and Alloys Magnesium and Alloys	Mineral lard oil Kerosene Soda water
Brass and Bronze	Soda water
Cast Iron	Dry
Cast Steel	Lard oil Mineral lard oil Soda water
Copper	Lard oil Soda water
Malleable Iron	Soda water Mineral lard oil
Monel Metal	Lard oil Soda water
Mild Steel	Mineral lard oil Soda water
Tough Alloy Steels Steel Forgings	Mineral lard oil Sulphurized oil Soda water
Steel, Tool	Lard oil Sulphurized oil Soda water
Wrought Iron	Mineral lard oil Soda water
Micarta and Bakelite	Mineral lard oil

TAPPING

Material	Cutting Compound
Aluminum Alloys	½ lard oil and ½ kerosene
Magnesium Alloys	Light mineral oil
Brass and Bronze	Light mineral oil Dry
Cast Iron	Small amounts of mineral lard oil, soap, or tallow
Copper	*"Cresol z-3" and paraffin oil #3313-4 and paraffin oil
Malleable Iron	Sulphurized oil
Monel Metal	Lard oil and kerosene Sulphurized oil
Wrought Iron Mild Steel	#3313-4 and paraffin oil
Tool Steel	Sulphurized oil Lard oil and kerosene
Stainless Steel	Sulphurized oil
Tough Alloy Steels Cast Steel Steel Forgings	Sulphurized oil
Rubber, Hard Fiber	Dry
Micarta, Moldarta and Other Molded Plastics	Dry

* "Cresol z-3" is an excellent heat dissipator and does not stain the work. It is rather expensive but may be used in a 10% solution of paraffin oil.

From copyrighted material prepared by Headquarters Wage Incentives Dept., Westinghouse Electric Corp.

MATERIALS & METHODS Engineering File Facts

NUMBER 108
February, 1946

METHODS: Finishing

Stripping Metallic Coatings

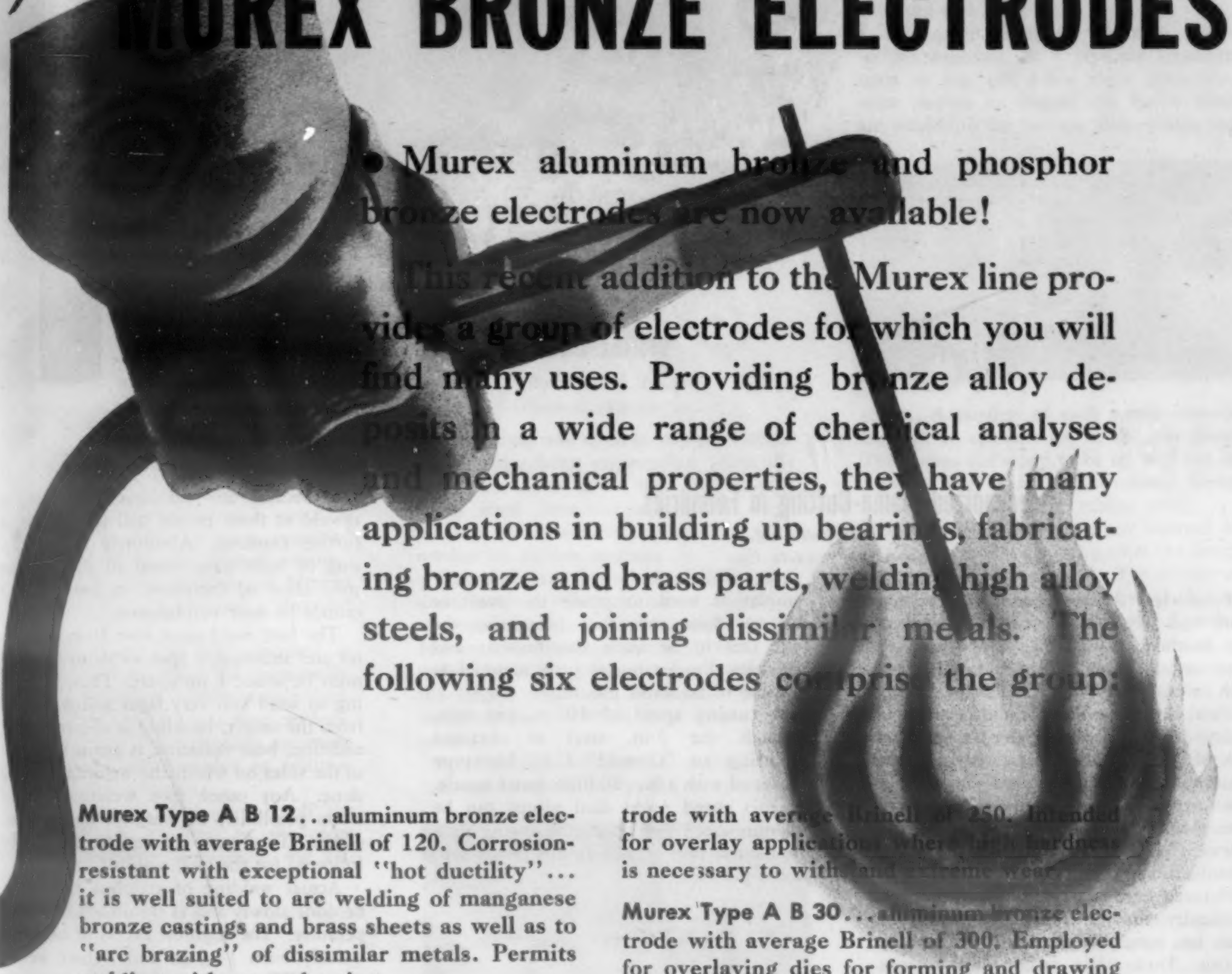
Coating	Basis Metal	Solution	Remarks
Cadmium	Steel	Hydrochloric acid, 12 oz.; antimony trioxide, 2 oz.; water, ½ pt.	Simple immersion at room temp. Rapid strip, but smut of antimony left on work.
		Ammonium nitrate, 1 lb.; water, to make, 1 gal.	Simple immersion at room temp. leaves clean, smut-free surface.
Copper	Nonferrous	Sodium sulfide, 28 oz.; sulfur, 2 oz.; water, to make, 1 gal.	Alternate immersion and brushing required to remove loose sulfide. Follow with 10% sodium cyanide dip. Formula suggested by Bell Telephone Labs.
	Zinc	Sodium sulfide, 1 lb.; water, to make, 1 gal.	Make the work the anode at 2 volts in a room temp. solution.
	Steel	Sodium cyanide, 1 lb.; water, 1 gal.	Make the work the anode at 6 volts in a room temp. solution.
Chromium	Steel or nickel	Sodium hydroxide, 6 oz.; water, to make, 1 gal.	Reverse current at 6 volts.
	Brass, copper or nickel	Sulfuric acid, 1 gal.; glycerine, 1 oz.; water, 1 pt.	Make parts the anode at 6 volts. Copper sulfate crystals may be added instead of glycerine in ratio of 4 oz. per gal. Solution will remove nickel undercoats.
		Hydrochloric acid, conc. or hydrochloric acid, 1 pt.; water, to make, 1 gal.	Use concentrated acid at room temp.; diluted acid at 125 F. Nickel undercoats will become passive and must be reactivated before rechroming.
Gold	Copper alloys, nickel alloys, ferrous metals	Sodium cyanide, 2 oz.; water, 1 pt.; hydrogen peroxide, ½ fl. oz.	Use solution by the pint and strip only a few pieces at a time to prevent violent gassing.

Coating	Basis Metal	Solution	Remarks
Nickel	Steel	Sulfuric acid, 1 gal.; glycerine, 1 oz.; water, 1 pt.	Make parts the anode at 6 volts. Copper sulfate crystals may be added instead of glycerine in ratio of 4 oz. per gal.
	Brass or copper	Fuming nitric acid, hydrochloric acid, 2 oz.; water, 1 gal.	An excellent nickel strip but extreme precautions must be taken to prevent dilution of the acid and subsequent attack on the underlying metal. Use gas carbon cathodes and reverse current.
Silver	Brass or nickel silver	Sulfuric acid, 19 parts by vol.; nitric acid, 1 part by vol.	Simple immersion in water free solution at 180 F.
	White metal	Sodium cyanide, 4 oz.; water, to make, 1 gal.	Reverse the current at 4 volts.
Tin	Steel, copper or brass	Hydrochloric acid 12 oz.; antimony trioxide, 2 oz.; water, 1 gal.	Simple immersion at room temp.
	Brass, bronze or copper	Ferric chloride, 10-14 oz./gal.; copper sulfate, 18-21 oz./gal.; 56% acetic acid, 40-60 fl. oz./gal.	Reactivate by additions of hydrogen peroxide to oxidize the reduced iron.
	Note: Navy Aeronautical Specification PC-12 recommends removal of tin coatings in an alkaline cleaner rather than in an acid bath.		
Zinc	Steel	Hydrochloric acid, 1 gal.; antimony trioxide, 3 oz.	Simple immersion at room temp.
	Brass	Hydrochloric acid, 15 oz.; water, to make, 1 gal.	Simple immersion at room temp.

General Note:

The majority of plated coatings, such as brass, bronze, cadmium, copper, zinc, gold and silver, are soluble in cyanide and can be stripped electrolytically if made the anode at 6 volts in the following solution: Sodium cyanide 12 oz., sodium hydroxide 2 oz., water to make 1 gal.

Prepared by George Black, Glenn L. Martin Co.



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MUREX ELECTRODES

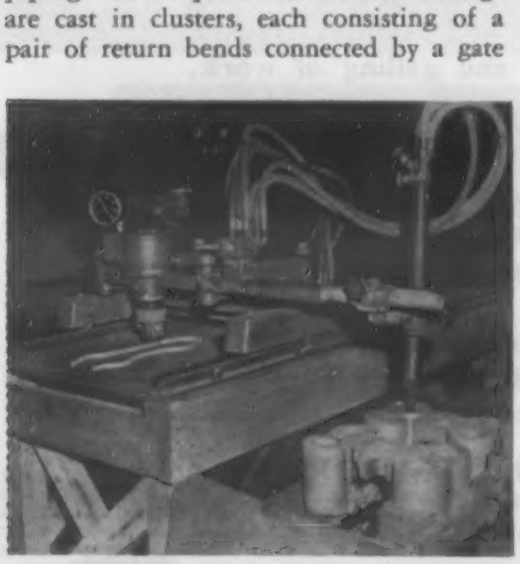
engineering SHOP NOTES

Mechanized Flame-Cutting in Foundries

By P. A. Spaulding,
Linde Air Products Co.

Foundries doing production casting work find oxy-acetylene cutting an excellent method of handling the diversified riser- and gate-removal jobs involved in such casting operations. The shape-cutting process, because of its contour-cutting capacity, can materially increase the production of finished castings by reducing the amount of grinding required per casting. The use of a templet-guided repetitive cutting setup with a machine such as the "Oxweld" CM-15 make production cutting a semi-automatic procedure.

Pictured here is a typical setup used by a foundry for the repetitive cutting of gates on return bends used in refinery piping. These plain carbon steel fittings are cast in clusters, each consisting of a pair of return bends connected by a gate 3 in. thick and 5 in. wide. To separate the fittings, two castings are clamped in the jig side by side and the necessary cuts are made in one continuous cycle in less than 10 min. A standard aluminum strip templet is used to guide the machine through these cuts, thus permitting the four cuts to be made continuously and automatically, leaving as little material as possible to be finish ground.



A cutting speed of 10 in. per min. through the 3-in. steel is obtained by using an "Oxweld" C-37 blowpipe equipped with a No. 80 high-speed nozzle. At this speed seven dual setups can be accommodated per hour, amounting to a production rate of 224 return bends separated per day.

Arc Welding Stainless Steel

by John H. Read,
Ergolyte Mfg. Co.

An outstanding application of a.c. electric arc welding on No. 14 gage and lighter stainless steel is carried on in the fabricating of all-welded stainless steel milk storage tanks of 100- to 2000-gal. capacity at the shop of A. M. Williams, Darby, Pa. Mr. Williams dispels the theory that light-gage metals are too difficult for arc welding, having done hundreds of feet of welds.

The first trick is in the fitting. It must be *perfect*. Edges to be fitted must be clean and straight. Irregularities in fitting necessarily result in uneven welds wherever these gaps occur. Heat radiation from larger welds produced at points of variance will cause the ill-fitting sheet of stainless metal to buckle or crack from strain. When this occurs, the damage is irreparable because any subsequent attempts to reweld at these points will only result in further cracking. Absolutely accurate fitting of light gage metal in the stainless steel class is, therefore, so basic that it cannot be over emphasized.

The butt weld must start from the center and subsequent spot welds to the edge must be about 1 in. apart. Thus, by starting to weld two very light and flat sheets from the center, buckling is eliminated. In addition, heat radiation is again restricted to the sides on which the welding is being done. Any other spot welding method offers possibility of warpage and cracked edges. This same procedure should be followed for the final welding.

Actual welding of stainless steel must be done slowly and at minimum heat temperature. The slightest excess of heat will quickly burn 14-gage and lighter weight metal. Whenever possible, all metals in the extremely light gage category should be welded flat. Mr. Williams uses 1/16-in. size rod for his 18-gage metal and 3/32-in. rods on 16-gage. Current range is confined to 41 amp.—not more than 46. This range permits ample penetration.

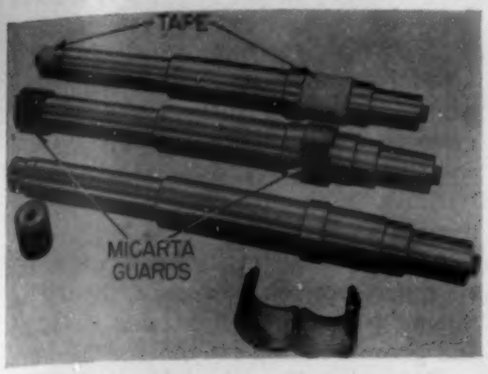
The quality of weld produced on stainless steel depends largely on the speed with which the arc is started. In the case of stainless steel, particularly, it is a distinct advantage to have a quick starting arc. This prevents damage to the metal by scratching. It is also of important advantage to beginners who ordinarily might scratch the surface with the rod.

If reverse welding on stainless steel is necessary—and it should be avoided—care should be taken to remove loose scale and to grind the surface smooth. After arc weld has been applied, no attempt should be made to repair or reweld by any other method. The light weight metal would not be able to withstand the increased heat strain.

Micarta Journal Guards

by E. J. Dick,
Westinghouse Electric Corp.

After the finish grind on shaft journals, considerable handling of the shaft is necessary before final assembly. If unprotected, the journal surfaces become scarred and scratched, requiring further finishing. Several means of protection are in general use, including tape and papers wrapped around the journal. But most of these have been unsatisfactory because of excessive time consumed in applying them to the shaft.



More modern and satisfactory are Micarta journal guards, hinged or threaded; hinged guard is used on the pinion end of the shaft; the threaded guard, on the commutator end. The hinged guard is secured to the shaft by wire wrapped around the pins on the hinged sections; the threaded guard is a section of Micarta tubing into which is inserted a threaded washer.

The guards are properly identified so that they can be separated for reuse easily. They are inexpensive and extremely durable, and are applied in a few seconds. Apparently they are adaptable to many items of round cross section in addition to shafting and journals.

In the accompanying photograph the top journals are protected by the older method, with tape. Just below, the Micarta guards are used.

Inconel Carburizing Boxes

by A. G. Zima,
International Nickel Co., Inc.

Carburizing boxes have to take a lot of punishment from heat and gases. Temperatures often run from 1500 to 2000 F. Conventional boxes average a life of 5,000 hr. and then must be discarded.

However, the use of Inconel, a nickel alloy, has greatly increased the life of carburizing boxes in the carburizing furnaces of the Axelson Mfg. Co., Vernon, Calif., a company that performs every type of commercial heat treatment in the processing of their own products.

In a process where 8,000 hr. is uncommon, carburizing boxes at Axelson have averaged 11,500 service hours. One box served a "hitch" of 12,094 hours at 1700 F, while another worked 11,782 hours at the same temperature. Both boxes proved economical on fuel.

Inconel boxes weigh about 100 lb. compared with 250 lb. for the usual cast alloy box of the same capacity. Since the normal furnace charge at Axelson consists of 18 boxes, a saving of 2,700 lb. of dead weight is effected with each charge. This 60% saving represents considerable reduction in fuel costs alone.

Axelson has made additional use of Inconel in the carburizing process by installing a hearth plate 18 in. by 40 in. by ½ in. in one of their oven type electric furnaces, used for clean hardening, normalizing, annealing and general heat treatment work. The plate shows no signs of deterioration, though has been in 18 mo. of constant service. In use, the carburizing box rests on the hearth plate, with thimbles raising the box bottom off the plate, permitting free heat circulation all around.

The boxes were fabricated by the Michigan Steel Casting Co.

(Courtesy of "Nickelsworth")

"Photo-Lofting"

By Nils H. Lou,
Glenn L. Martin Co.

Much time was saved in war production by photographing engineering plans directly on sheet metal, thus eliminating many steps formerly required in toolmaking. It materially reduces the time needed for factory tooling.

The process is known as photo-lofting, and involves the use of a specially equipped camera, the one at the Glenn L. Martin Co. plant weighing 10 tons, together with its superstructure, probably the largest camera in the world—yet as foolproof in operation as a simple box camera.

This method cut the time required for tooling the B-26 Marauder as much as

100,000 hr. The method has also been used by Boeing, Grumman, Beech and Chrysler companies. It has also been used by the Navy in building ships, and may now be used to hasten the delivery of automobiles, washing machines, refrigerators and other peace products.

In the accompanying photograph, the operator is sawing a templet to outlines photographed on templet material. Later, construction of assembly fixtures will be accomplished by mounting locators and clamps directly on the photographed layout.

Scoop on Truck for Scrap Handling

By C. B. Cook,
Elwell-Parker Electric Co.

In handling large quantities of metal borings and turnings for shipment to smelters, a motor car company uses a scoop of novel design. This enables it to transport metal from storage bins to road truck or to freight car by an Elwell-Parker power truck equipped with a swivel-mounted fork.

The scoop is made of steel plates welded together, in a box-like structure open at top and front end. Two separate sleeves to receive the fork's tines are welded to the bottom plate, inside the

scoop. A portion of each sleeve extends through an aperture cut in the rear plate. This causes the scoop to be set well out in front of the truck, one advantage being to protect the truck's rubber tires.

In operation, the tines are inserted in the sleeves and the truck pushes the scoop into a pile of loose metal. The course of the scoop is forward and upward due to the tilting mechanism on the forward part of the truck. The load is carried in an elevated position, to clear obstruction, with the scoop at an angle of about 45 deg. from horizontal in order to hold the maximum amount of material. It may be elevated if necessary to the full height of the fork's lift, 117 in. The scoop is emptied by being turned over by means of the rotating device on the truck, actuated by the truck's battery power.

Upper front edges of the scoop are cut away at an angle to facilitate its penetration into the metal. Material handled includes many tons of aluminum and aluminum alloy borings and brass turnings.

Shrink fits by extreme refrigeration are possible with materials other than metals. For instance, viewing ports of oil reservoirs in certain machines have Lucite windows. The conventional method of sealing the transparent plastic in these ports seemed inefficient to a certain maker of these machines. He tried cutting the Lucite exactly to the size of the hole, or slightly larger than the hole, so that the part could not be forced into the hole normally. The Lucite blanks were then placed in a freeze cabinet and brought down to minus 70 F. They shrank just enough to fit into the hole, and when they returned to room temperature they made a very tight joint with the metal walls of the port.

—John J. Hoenigman, Jr.,
Union Special Machine Co.

Milling Hard Welded Steel

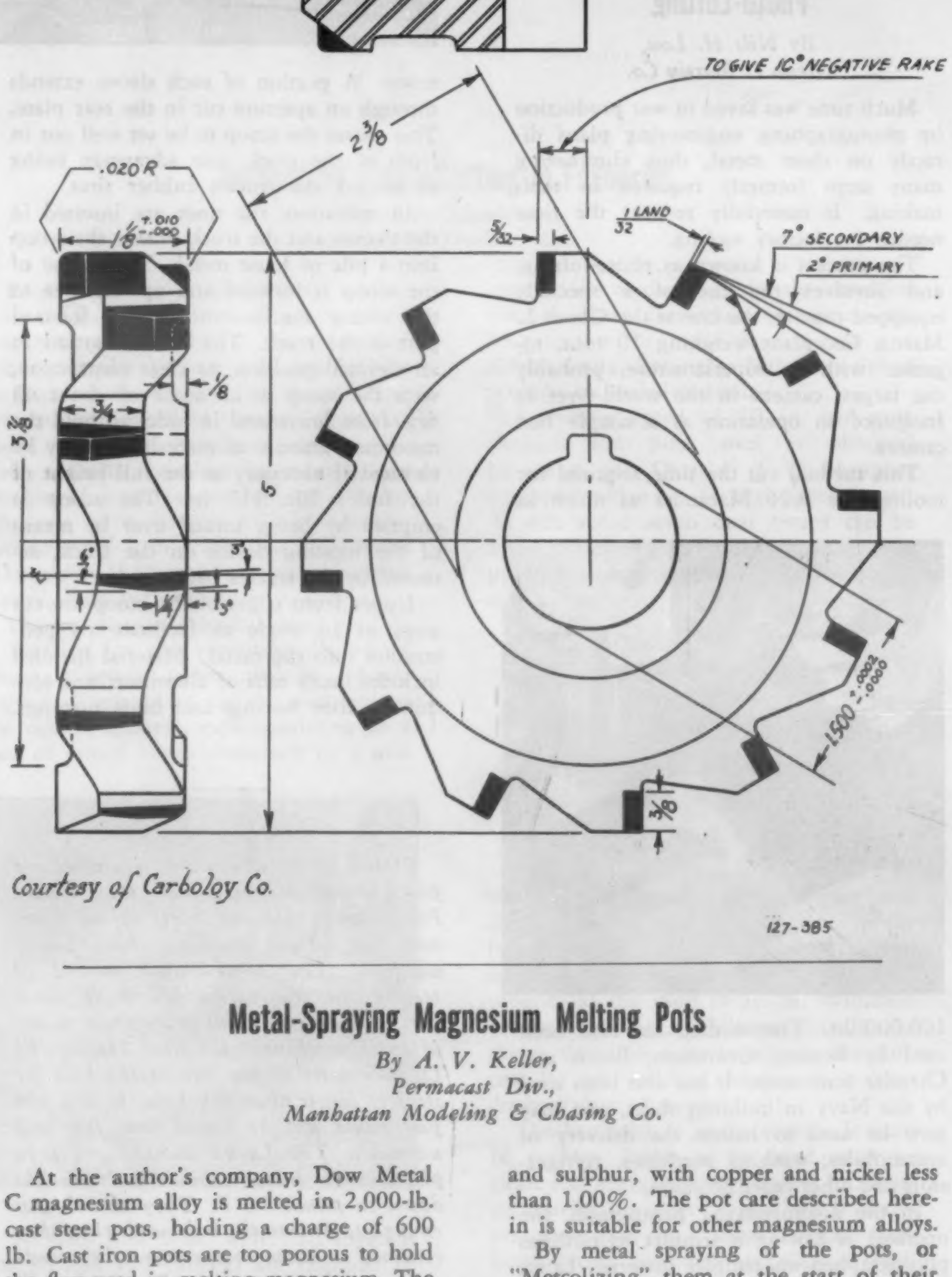
by Fred Lucht,
Carboloy Co.

The use of climb-milling in conjunction with a heavy flywheel is reported to have materially simplified the milling of very hard welded steel in one shop. A Carboloy cemented carbide tipped staggered tooth milling cutter is employed on this operation, and a high production rate of parts milled is being maintained.

The operation consists of milling a weld line 12-in. long in a welded steel receiver body for a 20-mm. gun. A cutting speed of 300 s.f.p.m. (229 r.p.m.) is used; a feed of 0.006-in. per tooth (16½-in. per min. table travel) is maintained; the maximum depth of cut is 1/16 in.; and an air blast is used as a coolant. The hardness of the steel adjacent to the weld—that is, of the metal actually being cut—is Rockwell 50 C, or approximately Brinell 495.

Climb-milling technique is employed, with a 150-lb. flywheel on the spindle to steady and smooth out the cutting operation as in fly-milling. Construction of the 12-bladed cutter is shown in the accompanying sketch. The cutter is tipped with Carboloy grade 78B, a cemented carbide combining toughness with good wear resistance and widely used for the general machining of steels.

Despite the fact that no annealing is performed on the welded parts before milling, and that the extremely hard steel is being cut at high speed, an average of 70 pieces are being satisfactorily milled between cutter regrinds.



Courtesy of Carboloy Co.

Metal-Spraying Magnesium Melting Pots

By A. V. Keller,
Permacast Div.,
Manhattan Modeling & Chasing Co.

At the author's company, Dow Metal C magnesium alloy is melted in 2,000-lb. cast steel pots, holding a charge of 600 lb. Cast iron pots are too porous to hold the flux used in melting magnesium. The pots used contain: 0.35 carbon, 0.70 manganese, 0.60 silicon, 0.06 phosphorus and sulphur, with copper and nickel less than 1.00%. The pot care described herein is suitable for other magnesium alloys.

By metal spraying of the pots, or "Metcolizing" them at the start of their service and periodically thereafter, the life of the pot is greatly extended. Comparison of two pots, identical at the start, show a working life of 456 hr. for an untreated pot and 2006 hr. for one metal-sprayed.

Each melting pot exterior surface is "Metcolized" with "Process 45," which protects against heat oxidation and practically inhibits scale formation. The pots are first grit blasted to remove all rust and dirt and to soften the contours of any surface irregularities. Then a special chromium-nickel alloy coating, 0.015-in thick, is sprayed on. Pure aluminum is metallized on top of this, then a special sealer by spray or brush. The first heat in service will cause alloying.

After 200 hr. use, each pot is removed from its furnace setting and inspected rigidly before resetting. At 2000 hr. the surface shows small wrinkles, with slight depth of carbide formation. They are given a hammer and metallurgical test and, if sound, are given a reconditioning treatment with grit blasting and retreatment with Process 45.

Among the defects in pots which the treatment corrects are scale, blowholes, minute cracks, lamination sand inclusions and general casting roughness. The worst condition is a line of weakness transverse to the direction of maximum tension stress—which means sure failure.

Many accidents in magnesium foundries have been caused by lack of care to melting pots. A leaking pot full of molten magnesium is a terrific hazard. Hot iron scale in the furnace pit is apt to promote an exothermic reaction with explosive violence, spreading the burning molten magnesium over a wide area.

At the author's foundry, before a new pot is put into use original residual stresses are normalized by heating in the furnace at 1000 F for 1 hr. per in. of wall thickness, and cooled very slowly to room temperature. The chief deterrent to pot life is the formation of scale on pot surfaces in contact with the heating flame.

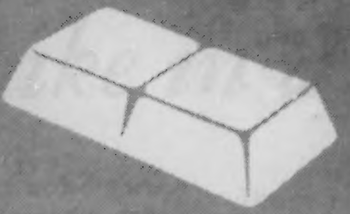
The 0.70% manganese, which is contained in the cast steel pot, is to resist creep. Though nickel would be a "natural" under most circumstances, it is not suitable here because of its affinity for magnesium.

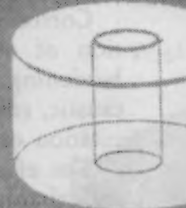
Pot scale is a complex and variable substance composed mainly of the chemical combination of iron and oxygen throughout, with which is incorporated mixtures of iron and other metallic constituents, plus various gases. Some sulphur is present, promoting ferric sulphates which also accelerate corrosion. Furnace gases (using city gas) liberate products of combustion which are responsible for scale formation. Scale represents a severe loss of metal, and has an unwanted heat insulating property.

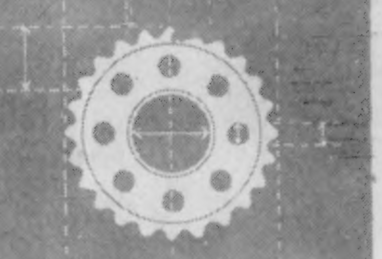
(Courtesy: Metallizing Engineering Co., Inc.)

When tapping material likely to tear, especially blind holes, it is well to pour the hole full of melted beeswax and tap as usual. If a small amount of turpentine is used in addition, with the wax, in certain soft metals, where backing out mars the thread, results are extremely gratifying.

—Darius Roberts,
Morgantown, W. Va.







MATERIALS & METHODS DIGEST

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Nonmetallic Materials

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METHODS and PROCESSES

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Fabrication and Treatment

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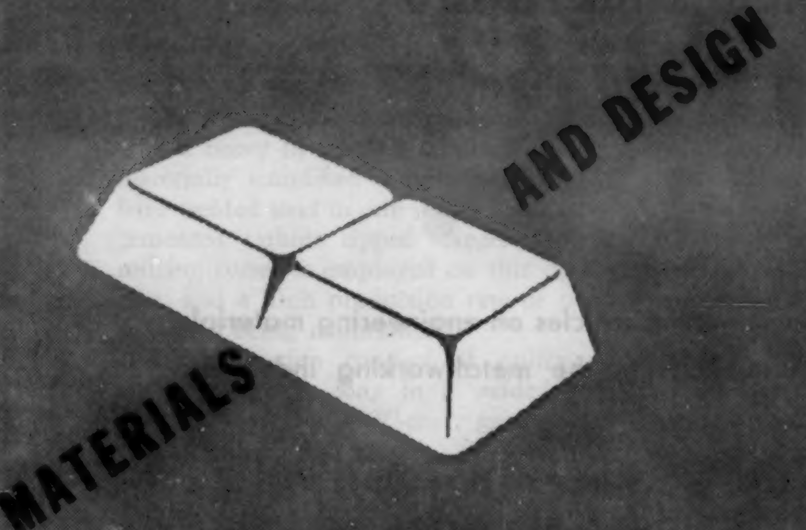

METALS and ALLOYS

Engineering properties and applications of carbon, alloy and stainless steels, irons and nonferrous metals and alloys. Selection and evaluation of metallic materials for engineering service. New alloys and modifications.

Corrosion Cracking in Mild Steel

Condensed from "Corrosion and Material Protection"

As the older problem of general corrosion was solved by wartime research, the importance of stress corrosion grew. The latter is caused wherein precipitation prepares the metal for corrosion cracking; cracks that are present produce high local stresses, and these stresses accelerate the precipitation.

Mechanical stresses accelerate the separation of two new phases from the supersaturated parent solid solution, and one of these and the parent phase form a suitable galvanic cell. The formation of new material at the grain boundaries and its dissolution is continuous. Therefore, the intercrystalline path of cracking can be foretold.

The important result based on this theory is that dissolved nitrogen, which is free to form iron nitride, is responsible for cracking. Nitrogen can be removed from steel, and the cracking tendency is removed with it.

Corrosion cracking and precipitation hardening of steel are related. There are five pertinent observations: Steel stress-corrodes; boiler embrittlement is an example of stress corrosion; boiler embrittlement is caused by the same agency as makes steel brittle, or ages it; strain aging is a result of precipitation; steel is a precipitation hardening metal.

The best known example of stress corrosion in the use of steel is nitrate attack. Here the intercrystalline cracks occur only in a region of high stress and the solution is concentrated and mildly corrosive. Boiler embrittlement is very penetrating and so destructive of the metallic strength that boiler explosions occur.

Steel deoxidized with aluminum has excellent resistance to boiler cracking. Nonaging steels are resistant to caustic embrittlement and nitrate attack. The same heat treatment which makes steel essentially free from strain aging—quenching from the upper critical temperature followed by annealing below the critical and slow cooling—also improves corrosion resistance. This treatment would tend to make a sorbitic steel, which has a high resistance to caustic embrittlement.

Corrosion cracking depends on precipitation of some material rather than upon hardening, by aging, itself. Boiler, or caustic, embrittlement depends on the precipitation of iron nitride from ferrite.

The effect of elements such as aluminum and titanium is to render the steel nonaging and, by combining with the nitrogen, prevent nitride precipitation. Phosphorus and oxygen decrease the solubility of nitrogen and carbon in ferrite.

—J. T. Waber & H. J. McDonald. *Corrosion & Material Protection*, Vol. 2, Nov. 1945, pp. 13-16.

Fatigue Strengths of Magnesium Casting Alloys

Condensed from "Magnesium Review"

In the laboratories of Magnesium Elektron, Ltd. much attention has been directed towards the statistical determination of the various mechanical properties of the standard magnesium-base alloys, this paper giving the results of Wohler fatigue tests on commercial magnesium-base casting alloys.

As far as alloy compositions are concerned, British and American practice show some divergence. In Britain Elektron AZ 91 (9½% aluminum, 0.4% zinc, 0.3% manganese) and Elektron A 8 (8% aluminum, 0.4% zinc, 0.3% manganese) are the standard casting alloys. In the United States preference is given to the higher zinc content alloys, and Dow H, AM 265—the old Elektron AZG—(6% aluminum, 3% zinc, 0.2% manganese) and Dow C, AM 260 (9% aluminum, 2% zinc, 0.2% manganese) are the most widely used.

All four types were tested, in the as-cast state, and in all conditions of heat-treatment, such as annealed, solution-treated and fully heat-treated. Stress values have been taken as a basis of comparison, for an arbitrary number of cycles.

The as-cast condition gives very slightly higher values for A 8 and AZ 91 than for AZG and AM 260. The annealed condition gives highest values for AM 260 and lowest for AZG. AZ 91 is close to AM 260 and A 8 just above AZG.

The solution treated condition gives highest values for AZ 91 and AZG, with A 8 and AM 260 very slightly lower. This condition generally gives the best results. The fully heat-treated state gives highest values for AZG and AM 260 and lowest for A 8. This condition gives the poorest results.

The maximum difference between all the results for the unnotched alloys in any one condition is 0.6 ton per sq. in., shown between A 8 and AM 260 in the fully heat-treated condition, or 4.7 and 5.3 tons per sq. in., respectively. The highest and lowest values regardless of condition are 6.0 tons per sq. in. for annealed AM 260,

solution-treated AZ 91 and AZG, and 4.7 tons per sq. in. for fully heat-treated A 8.

For the notched tests the most outstanding results are in cast and solution treated AZG, almost insensitive to notching. Annealed and full heat-treated, it shows notch sensitivity greater than, or equal to, that of the other alloys. Notch sensitivity of A 8 and AZ 91 is greatest as cast, being progressively reduced through annealing, solution and full heat-treatments.

The order of notch sensitivity for AM 260 is as-cast, solution treated, fully heat-treated, annealed. As-cast is the least and annealed the most notch sensitive.

Notch sensitivity is low generally in the fully heat-treated state. However, notch sensitivity is not a fundamental property, though important, and varies greatly with the type of test. Tensile and fatigue properties are not closely tied together in these alloys.

—F. A. Fox & J. L. Walker. *Magnesium Rev.*, Am. Edition, Vol. 4, Oct. 1944, pp. 105-114.

Zirconium in Vacuum Tubes

Condensed from a Paper of the Electrochemical Society

Progress in zirconium technology has been very rapid in recent years. Most of the published work deals with the use of zirconium oxide in ceramics, refractories, and glazes. The metal is used chiefly as a degassing agent in the casting of metal and as an alloying agent in producing anti-corrosion and high-speed tool steels. Recently the metal has been utilized in the vacuum tube industry.

In using the powdered metal in the inner structure of the vacuum tube, advantage is taken of its dual role as a getter and as a black body. The plate, when provided with a black outer surface, makes possible much higher power output from a tube of a given size. The binder most used for applying the powder is a nitrocellulose lacquer.

A silica sol-zirconium suspension developed by Bell Telephone Laboratories offers advantages in firmer binding and less easily ignited material. Application is made by spraying or by brushing.

Zirconium had been employed in steel manufacture as a scavenger, and in detonators and pyrophoric mixtures. Comparatively large percentages of impurities produced no ill effects. For vacuum tube work purities in terms of hundredths of a per cent instead of per cent were required, and it was necessary to heat plates coated with zirconium to 1300 C (2370 F) in a vacuum to remove volatile metals before assembling the plates into the tubes.

The value of zirconium as a getter depends upon its ability to combine with many gases, especially oxygen and nitrogen. Burning zirconium liberates 2830 calories for every gram of metal converted to zirconia, and the temperature of the mass approaches 3000 C (5430 F).

The ignition temperature of the dry powder ranges between 180 and 285 C (356 and 545 F), depending on particle size and possibly on oxide content. Burning zirconium behaves like burning magnesium in that it is capable of removing oxygen

(*Continued on page 494*)


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from water, leaving the hydrogen to unite with oxygen from the air.

Dry zirconium in bulk constitutes a serious fire hazard. Because of the high temperature of combustion, the fire will quickly spread to nearby combustibles, and water is worthless in attempting to extinguish a sizeable fire—in fact, increases the hazard.

The low kindling point makes ignition by a static spark or friction possible. The dust is explosive when mixed with air in the proper proportions. When possible, zirconium should be kept wet with a liquid such as water or alcohol.

Zirconium in hydride form protects the metal against oxidation during seal-in. Technics and hazards are about the same as for the metal, except for higher kindling temperature.

—Alfred N. Rogers. Paper, *Electrochemical Soc.*, Preprint No. 88-19, Oct. 17, 1945, 6 pp.

Fatigue Strength of Hardened Steels

Condensed from "Z. Ver. deut. Ing."

Although it is quite well known that structural parts which have been ground and have received scratches in this treatment show an inferior fatigue strength under operational stresses, no definite numerical values have so far been established. Such scratches originate only in a wrong grinding practice of hardened and case-hardened structural steels and hardened tool steels if the Rockwell C hardness exceeds 58 to 60 or the Vickers hardness 700; they are observed only by the magnetic test for cracks.

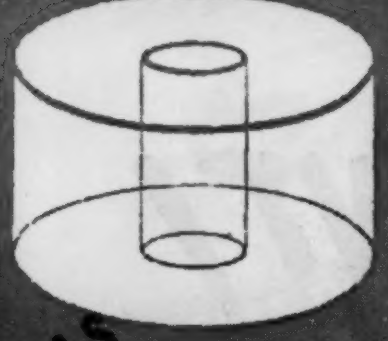
Bending fatigue tests were therefore made with a chromium-molybdenum case-hardening steel ECoM 80 and, for comparison, a molybdenum-free case-hardening steel EC 80, with flat specimens of 2.5 x 15 sq. mm. section and 8 x 25 sq. mm. section. The results showed that the fatigue strength of both steels with about 0.5-mm. deep case-hardening of 60-62 Rockwell C surface hardness is lowered by about two-thirds and in nitriding steels with 0.5-mm. deep nitrided layer at 880-900 Vickers surface hardness by about one-third, as compared with the bending fatigue strength of undamaged, hardened samples of the same heat-treatment.

Hardened steel of about 110 kg. per sq. mm. (156,500 p.s.i.) loses about 20% of its core strength by grinding with too hard grinding wheel or too great feed. In order to avoid grinding scratches or cracks, not only the grinding wheels must not be too hard but the grinding conditions, as speed, feed and advance, should be moderate, and wet grinding with continuous flow of cooling agent of not less than 20 C should be applied. Work piece and grinding wheel should preferably touch in a line, as surface touch may result in burning.

Experience has shown that the sensitivity for grinding cracks is less if the surface hardness of case-hardened steels is below 60-62 Rockwell C, and the case-hardened layer does not have a strongly pronounced cementite structure. The danger of grinding cracks is also diminished by stress-relieving after the final hardening at 160 to 170 C for at least 1 to 2 hr.

—H. Staudinger. *Z. Ver. deut. Ing.*, Vol. 88, Dec. 23, 1944, pp. 681-686.

MATERIALS AND DESIGN



NONMETALLIC MATERIALS

Design-uses of plastics, plywood, fibre, glass, rubber, ceramics, etc. as engineering materials. Composite metal-nonmetal combinations. New types and forms of nonmetallic materials.

Melamine-Bonded Fiberglas Laminates

Condensed from "Plastics"

Developed to meet wartime requirements for an insulating panel board that would not give off toxic fumes when scorched, melamine-bonded fiberglas laminate possesses mechanical strength, good electrical characteristics, excellent heat resistance, and low cold and hot flow.

Properties are affected by the method of preparing the glass cloth. Best mechanical strength results when the binder on the cloth is carmelized by heating, but not completely removed, as it was in heat cleaning. Non-pyrolized glass fabric, and that which has been heat-cleaned, is white when laminated with melamine resins. The pyrolized materials are so superior that they are now the only ones commercially available.

Exceptionally high mechanical strength is the outstanding property of melamine-bonded fiberglas laminates. Tensile strength of Phenolite MGB-811 is about three times, and flexural and compressive strengths are about twice those of other types of commercial laminates. Impact strength is also very high. The modulus of elasticity is about three times that of any heretofore available laminate.

Another valuable characteristic is high dielectric strength at 60 cycles. It becomes an excellent insulator that can be sheared, cut with abrasive wheels, punched, or drilled, while being tough, strong, and heat-resisting. Power factor at 1000 kilocycles is 0.016, which makes it particularly suitable as radio condenser stator support insulation.

Submergence in water during a test decreased the insulating value, but it was still high enough to equal good dry insulators of other materials. The high insulation value is lost under direct current voltage stresses when exposed to humid conditions.

Melamine-bonded fiberglas is also the hardest of the laminates. It has less cold flow or creep than any other laminated plastic under steady stress. While some other insulators have less cold flow, they cannot be fabricated and are too brittle to be riveted.

The plastic laminate does not soften appreciably at elevated temperatures. Tests upon samples heated to 135 C (275 F) for 2 min. show no appreciable drop in hardness from room temperature values.

Although the material will burn in high temperature flames, it gives off little carbon monoxide. It can be used for continuous service in temperatures to about 300 F. Four weeks heating at this temperature caused no loss of strength.

—G. A. Albert. *Plastics*, Vol. 3, Dec. 1945, pp. 82, 105-108.

Allyl Esters

Condensed from "Modern Plastics"

Volume change during polymerization has limited the use of allyl esters as plastics. A new allyl ester developed by B. F. Goodrich Chemical Co. overcomes this limitation. Called Kriston, the new material has improved chemical resistance, better electrical and optical properties, is of the thermosetting type, and possesses exceptional heat and flame resistance.

The new plastic is only about one-half as heavy as glass, and can be ground and polished with considerably more ease. It has been suggested for optical contact lenses, viewing glasses in chemical process control instruments, cast camera lenses, decorative pieces, window display, and illuminated sign parts.

Tests indicate that the material is relatively stable electrically, over a range from −10 to +140 C (14 to 285 F), and while inferior to polystyrene and polyethylene at room temperature, it maintains its properties at elevated temperatures.

The material seems suitable for laminated structures. Glass fabric, cotton fabric, paper, asbestos and wool have been used. With glass fabric the laminate is almost transparent because of the similar refractive indices of the ester and the glass fibers.

The allyl monomer as supplied by the manufacturer is a water-clear sirupy liquid of high boiling point. It can be stored indefinitely in the absence of the catalyst and at O. C. Polymerization is accomplished by heating the monomer and catalyst to about 70 C (158 F) for a time, depending upon the size and shape of the part to be cast. Higher temperatures will shorten the time required.

For a cast form, the material is poured into molds and the whole heated to 70 C until all bubbles have risen to the surface and have broken. Cooling should take place gradually.

For laminated structures, the monomer-catalyst mixture is prepared as before, and the reinforcing fibers are treated with the

mixture by any convenient method. The whole is then heated at 70 C to complete polymerization.

The allyl polymer is best cut by sawing, preferably with a band saw. Sawmarks may be removed with No. 3 sandpaper or its equivalent. Polishing is done with jeweler's rouge suspended in light oil, spread on a soft felt wheel. High-speed wheels give the best results.

Colors are obtainable by dyeing the polymer, or preferably by dyeing the monomer before casting.

—Sam L. Brous. *Mod. Plastics*, Vol. 23, Dec. 1945, pp. 107-110.

Cellulose Propionate—New Plastic

Condensed from a Paper of the Society of the Plastics Industry

Chemically speaking, Forticel is plasticized cellulose propionate. It was developed as a result of studies showing that sensitivity to moisture, hardness, and rigidity decrease as the number of carbon atoms in the acid increase. It was predicted that the propionate would have low sensitivity to moisture while still retaining adequate rigidity.

The new plastic has unusually high impact resistance, low moisture absorption, good dimensional stability, and low warpage under hot humid conditions. Properties can be varied over a wide range by plasticizing, so that a whole family of plastics can be obtained.

The flow temperature for a typical composition is given as 161 C (323 F), a value that may seem to be high. However, the molding temperatures are moderate, and good parts have been obtained over a range of 80 F, as compared with a span of 30 to 50 F for other cellulose ester plastics.

It has excellent flow characteristics under injection molding conditions. Apparently the material softens more suddenly at molding temperatures than does cellulose acetate, and flows more easily.

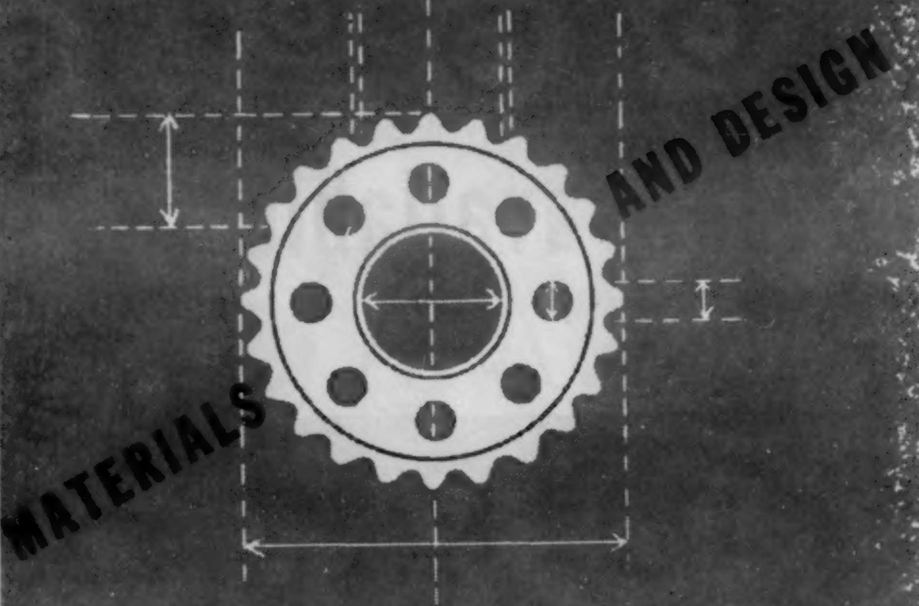
The flow and set-up speed result in very satisfactory injection cycles. Runs in a variety of dies in comparison with all cellulose plastics have shown molding cycles as fast as any of them.

Although most of the work that has been done to date has been concentrated upon molding materials, preliminary studies have been made upon plastic sheets and film made with cellulose propionate. It was indicated that film and sheet material will have advantages in flatness, dimensional stability, and toughness.

Since the cellulose esters become more plastic as the number of carbon atoms in the acid chain increases, less plasticizer is required than for cellulose acetate. For compositions of comparable flexural strength, it is less than 50% of that required for cellulose acetate. The low plasticizer level results in excellent retention of plasticizer upon aging.

Cellulose propionate is compatible with cellulose acetate butyrate in all proportions, but not with cellulose acetate, with ethyl cellulose plastic, nor with resinous plastics, such as polystyrene. Benzol has an appreciable solvent action, and a wide range of non-volatile plasticizers is available for compounding.

—Ralph H. Ball. Paper, *Soc. Plastics Industry*, Nov. 1, 1945, 8 pp.



GENERAL PRODUCT DESIGN

Selection, applications and design of parts made by various fabricating methods or made of special materials. Properties and uses of finishes and coatings. Design and materials for specific products or fields. General engineering design trends or principles.

Properties of Riveted Joints

Condensed from a Report of the National Advisory Committee for Aeronautics

The strength of representative types of flush-riveted joints has been determined by testing 865 single-shearing, double-shearing and tensile specimens representing seven types of rivets and 18 types of joint. The results show the stress at failure, type of failure and d/t ratio (rivet diameter to plate thickness).

In general, dimpled joints were appreciably stronger than countersunk or protruding-head joints, but their strength was greatly influenced by constructional details.

Dimpling is used to a greater extent than countersinking in thin sheets of aluminum alloy used as an exterior skin in aircraft, but where sheets are joined to a relatively thick structural member, the sheet is often dimpled and the member countersunk.

An examination of single-shearing specimens discloses that the critical shearing stress for protruding head rivets is the same as for machine-countersunk rivets of the same alloy, but for the protruding head rivets, the critical bearing stress and the d/t ratio at which the bearing stress becomes critical are higher.

When shearing stresses are critical, joints in the Alclad material are slightly stronger than joints in 24ST and 24SRT, and vice versa when bearing stresses are critical. There is no significant difference between press-driven and hammer-driven rivets.

The difference between results from different manufacturers was considerable. In the stronger joints, the sheets conform more closely to each other and to the rivet, with little or no void between them and with a greater portion of the manufactured head in contact with the sheets.

Details of design and technique of fabrication predominate in determining the strength of a dimpled joint. For sheet failure, the stress that is actually critical is either a hoop stress around the edge of the hole or, for some dimpled joints, a combined shearing and bending stress at the most sharply curved section of the dimple.

The low tension strength of some joints was definitely identified with the cracks in the sheet at the rim of the dimple. The mechanical properties of a joint, its surface smoothness, the occurrence of cracks and the cost of production are all determining factors in selecting a flush-riveted joint. It seems impractical to rate individual types or to make a general statement relative to their merits.

Almost all the dimpled single-shearing joints having a d/t ratio above 2.1 showed an important advantage in strength over machine-countersunk joints. This value of d/t is probably the lower limit at which satisfactory dimpling can be performed.

Tests emphasize the need for avoiding severe bends when flanging the sheet to form the dimple. There is a recent trend toward a larger included angle of the manufactured head (100 to 120 deg.), the smaller bend angle at the dimple permitting a sharper bend without danger of rupture.

—W. C. Brueggeman & F. C. Roop. *Nat. Advisory Committee of Aeronautics,* Report No. 701, 1940, 29 pp.

Wood vs. Metal Aircraft

Condensed from "S.A.E. Journal"

Early results of tests on structural parts of wood for plywood-covered aircraft by Beech Aircraft Co. indicated that following the same practice used in all-metal construction was impractical. Primary reasons were the wide variation of the properties of the wood and the manner in which the load was applied to the wood member.

A principal limitation in the use of wood aircraft construction is size of aircraft. As the size of aircraft increases, it becomes more difficult and impractical to use wood as a structural material.

Comparative analysis of the construction of structural members on the basis of wood and dural as materials was made. In the case of a 7500-lb. airplane, a spar and skin covering made of metal weighed 61% that of wood. In a 2400-lb. airplane, the metal construction weighed 82% that of wood. These results show that a substantial weight saving is effected through use of metal construction, and that the strength-weight ratio

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of wood versus metal aircraft holds throughout the practical range of aircraft size.

Experience shows that it is impractical to use skin thicknesses of less than 0.020-in. in dural and 3/32 in. for plywood covering. In spars, it is impractical to use webs under 1/8 in. for single webs and 3/32-in. plywood for double webs. There is no objection to a minimum web thickness of 0.020 in. in dural.

In considering costs of construction, the cost of structural fabrication may be only a small portion of the total cost of the airplane. On a typical airplane, only about 24% of the weight empty can be credited to possible substitution of wood. Wood materials cost more than metal. Waste wood is burned, whereas scrap dural is sold.

For limited production, small designs, and experimental types, tooling expense may greatly favor wood construction. Actual production experience indicates that there is little, if any, advantage of wood over metal construction.

Plywood requires a fabric cover to give all-weather protection and satisfaction. This adds extra weight and expense. Metal structures require no external paint finish.

—Herb Rawdon. *S.A.E. Journal*, Vol. 53, Dec. 1945, pp. 691-712, 718.

Cavitation in Centrifugal Pumps

Condensed from "Transactions of the American Society of Mechanical Engineers"

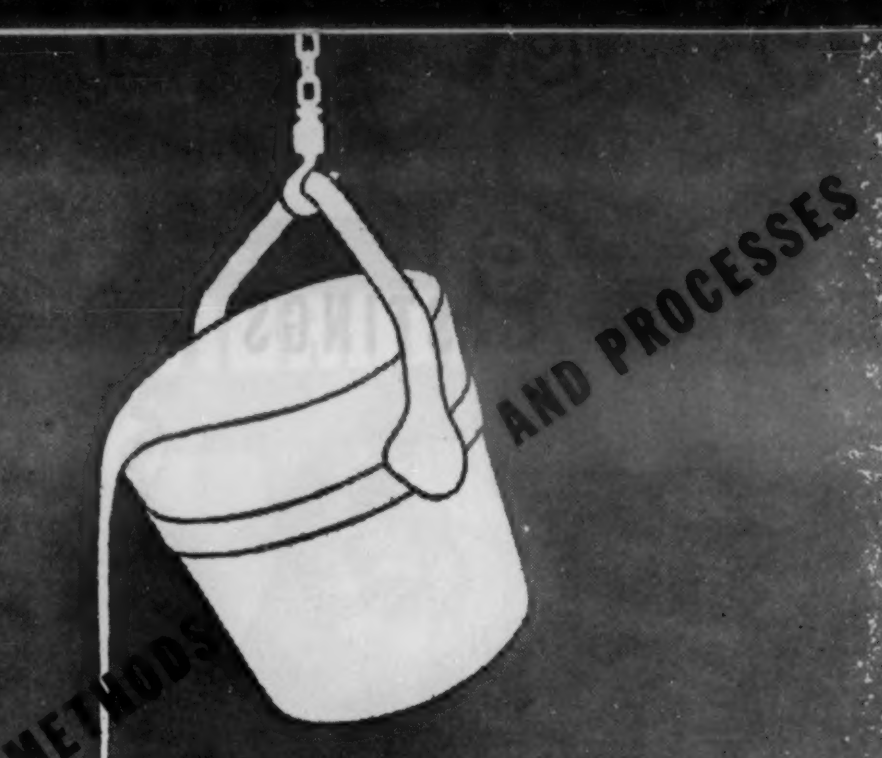
The problem of cavitation in centrifugal pumps became particularly serious with the introduction of high-speed pumps. Cavitation is hereby defined as referring to conditions within the pump, where, due to local pressure drop, water-vapor-filled cavities are formed that collapse as soon as such vapor bubbles reach regions of higher pressure on their way through the pump.

According to present knowledge, cavitation has been established as of an entirely mechanical nature. Signs of cavitation are noise, vibration, and, most reliable, drop in efficiency. The harm caused by cavitation is less pronounced in a large pump than in a small model for the same cavitation coefficient.

Means for avoiding or reducing cavitation are (1) most important, knowledge of the cavitation characteristics, available or obtainable by tests; (2) suction conditions, eventually increase of suction pipe size and reduction of its length; (3) increase in the number of vanes, and (4) use of special materials to reduce the pitting of pump parts by cavitation.

The noise and vibration caused by cavitation can be reduced or eliminated by the admission of a small amount of air to the pump suction. A table gives the losses of material by cavitation of 12 Krupp steels and 10 bronzes; cast steel behaved worst, and manganese bronze showed a still greater loss in the same time. Among the best materials were steels with 0.2% carbon, 7% nickel and 20% chromium, a (Krupp) bronze DB16, and a Corrix bronze (88% copper, 9.0% aluminum, 3% iron).

—A. J. Stepanoff. *Trans. Am. Soc. Mech. Engrs.*, Vol. 67, Oct. 1945, pp. 539-552.



MELTING and CASTING

Melting, alloying, refining and casting methods, furnaces and machines. Iron and steel making, nonferrous metal production, foundry practice and equipment. Die casting, permanent mold casting, precision casting, etc. Refractories, control equipment and accessories for melting furnaces.

Electric Induction Steel

Condensed from a Paper of The Electrochemical Society

The high-frequency induction furnace made its debut in 1916 and was immediately successful for melting laboratory and small batches of steel. By 1930 the furnace was considered indispensable to certain branches of the steel industry.

Heating is proportional to the ampere-turns applied to the furnace inductor and to the frequency. Stirring of the charge is proportional to the ampere-turns only. If the frequency is high, heating is excellent but stirring is poor; if the frequency is low, stirring is excellent but heating is poor. A compromise frequency is the solution.

A frequency of 1,000 cycles will serve for any practical melt above 300 lb., and has become almost standard for steel melting equipments rated at 175 kw. and above. Frequencies of 3,000 to 12,000 cycles can be used for melts larger than 300 lb., but at a disadvantage. For laboratory and very small scale melting, frequencies as high as 20,000 to 60,000 cycles, obtained from spark gap converters, are often used.

The advantages for alloy steel melting are numerous: Fast, carbon-free melting, the inherent electromagnetic stirring of the molten bath, flexibility, and control of the melt are the chief advantages. High efficiency and comfortable working conditions are also important. The circulation of the bath insures that each part of the finished product will have the same analysis as every other part.

Such furnaces are generally more costly than arc furnaces, just as the arcs are dearer than open hearths. Suitable for the induction furnace are top grade tool and alloy steels, high nickel and high chromium alloys, magnet steels and other high priced and critical steels.

Costs continually decrease. The royalty, which on small furnaces once amounted to \$80 a kilowatt, has finally been eliminated. At least as much as \$5,000 has been knocked off the cost of a small melting equipment. The induction furnace is almost fool proof.

Furnace controls are so simple that relatively unskilled workers can run them. Of course, special attention must be given to working out a suitable melting and operating technique, after which it is easy.

For small scale work one man can do the melting, prepare the molds and line the furnace. For large scale work the charging and melting can be done by one man but others divide the remaining tasks. Furnaces from the 5000-lb. size down are the most popular.

The centrifugally cast gun was an induction furnace product, cast in a single 5000-lb. melting furnace. In Europe, 8- and 10-ton furnaces are fairly common, but the largest in the United States are the 4-ton units of Carnegie-Illinois Steel Corp.

—F. T. Chesnut. Paper, *Electrochemical Soc.* Preprint No. 88-17, Oct. 12, 1945 meeting. 7 pp.

Metallurgy of the Side-Blown Converter

Condensed from "Stahl und Eisen"

An experimental investigation was made with a side-blown converter of 1000 kg. charge and a blowing time of 16 to 18 min. during which the converter was 5 to 6 times tilted. Additions were made of 7 kg. of 74% ferrosilicon at igniting, 19 kg. of 74% ferromanganese after the end of blowing in the converter, 6 kg. of 75% ferrosilicon and 1.5 kg. aluminum in the ladle. Results of five melts were studied.

There exists, between the bottom-blown large converter and the side-blown small converter, not only a difference in the behavior of the nitrogen, but also in the progress of the metal-slag reactions. While in the large converter the reactions follow, with the exception of the combustion of carbon, the equilibrium conditions, the equilibrium is established in the side-blown small converter only near the end of the melting period so that during the other part of the melting period a strong unequilibrium exists.

The reason for this condition is the too-high ferrous oxide content of the slag,

which is brought about by the wind blown onto the melt whirling up iron particles suspended in the slag and oxidizing them to a very large extent, similar to the oxidizing action of the furnace gases in the open-hearth. The velocity with which the ferrous oxide is then used up depends largely on the physical condition of the slag.

The high viscosity of the acid silicates poor in maganous oxide are particularly unfavorable for reaching the equilibrium quickly, while the increasing temperature in the course of the melting process facilitates the exchange. The higher ferrous oxide content of the slag in the side-blown converter could have, in the basic process, the effect that dephosphorization occurs at an earlier stage.

Another peculiarity of the basic process with side-blast could be seen, in that the pressure against which the carbon monoxide originating from the burning carbon is higher than in the bottom-blown converter. Here the carbon monoxide partial pressure is much lower than one atmosphere while during the dephosphorization the oxygen is bound only as liquid oxygen; for this reason, to a given oxygen content belongs a smaller carbon content and vice versa.

With side-blast this is not the case; the conditions will rather be similar to those in the open-hearth. This would mean in practice that when operating to obtain a definite phosphorus content and thus, under otherwise same conditions, a definite oxygen content, the carbon content will have to be somewhat higher.

If the decrease in sulphur observed in acid melts is a peculiarity of the side-blown converter, it could be expected that the basic slags lose sulphur by oxidation in the side-blast and thus a stronger desulphurization takes place than in the bottom-blown converter.

—H. Wentrup & O. Reif. *Stahl u. Eisen*, Vol. 64, June 1, 1944.

Microporosity in Magnesium Alloys

Condensed from "Foundry Trade Journal"

Magnesium alloys for microporosity tests were melted in iron crucibles, covered during melting with Melrasal flux Z, and refined by stirring at a temperature of 700 to 750 C (1290 to 1380 F) with Melrasal flux E. In general, the alloys were superheated to a temperature 250 C (450 F) above the liquidus temperature, *i.e.*, to about 850 to 900 C (1560 to 1650 F) for most alloys. During the superheating the alloys were protected with Melrasal flux E.

Gas-melting furnaces were used for most of the work. Generally, the alloys were cast in a highly permeable silica sand mixture containing 6% sulphur, 0.5% boric acid, 4% bentonite or 5% Fulbond No. 1, and 2 to 2.5% water.

The main types of specimens were as follows: DTD bar poured inclined 30 deg. to vertical, top-run bar with feeder of varying size generally too small to give complete feeding, bottom-run vertical bar with feeder head at top (conventional bar), bottom-run bottom-fed bar (inverted bar),

A FEW FACTS ABOUT CORHART PRODUCTS

Corhart Electrocast Refractories are high-duty products manufactured by melting selected and controlled refractory batches in electric furnaces, and casting the molten material into molds. After careful annealing, the finished shapes are ready for shipment. Dense, high-melting refractories, they are especially designed for resistance to corrosive action.

PRODUCTS

CORHART STANDARD ELECTROCAST is a high-aluminous refractory.

CORHART ZED ELECTROCAST is Zirconia-bearing.

CORHART ELECTROPLAST is a high-temperature plastic refractory made from Standard Electrocast which has been ground and crushed. Especially designed for ramming. Furnished dry.

CORHART MORTAR is a high-quality cement for laying up Electrocast, clay brick, or any aluminous refractory.

CHARACTERISTICS OF STANDARD ELECTROCAST

POROSITY: Less than 0.5%—therefore virtually no absorption.

FUSION POINT: Cone 38 without any appreciable softening below that point.

HARDNESS: 8, Mineralogist's scale.

SPECIFIC GRAVITY: Blocks weigh approximately 183 lbs. per cu. ft.

COEFFICIENT OF EXPANSION: 0.000006 between room temperature and 900° C.

SPECIFIC HEAT: 0.25 cal. per gm. per °C. at 980° C.

THERMAL CONDUCTIVITY: 25 BTU per sq. ft. per hour for gradient of 1°F. per inch.

COMPOSITION: Standard Electrocast is of an aluminous crystalline nature.

CORROSION: Because of low porosity and inherent chemical make-up, Corhart products are highly resistant to corrosive action.

APPLICATIONS

Most heat processes present spots where a better refractory material is needed in order to provide a balanced unit and reduce the expense of repeated repairs. It is for such places of severe service that we invite inquiries regarding Corhart Products as the fortifying agents to provide the refractory "balance" desired.

The following is a partial list of applications for which Corhart Products are suggested:

ELECTROLYTIC CELLS — for production of Magnesium and other light metals.

SILICATE OF SODA FURNACES — sidewalls, bottoms, and breastwalls.

HEARTHS AND SMELTERS — for non-ferrous metals.

ALKALI AND BORAX MELTING FURNACES — fast-eroding portions.

GLASS FURNACES — the entire installation of flux walls and bottoms, breastwalls, ports, tuckstones, forehearths, recuperators, etc.

RECUPERATORS—tile, headers, separators, etc.

ENAMEL FRIT FURNACES — flux walls and bottom.

BRASS FURNACES — metal contact lining.

ELECTRIC FURNACES — linings for rocking type, and rammed linings of Electroplast for this and other types.

BOILERS — clinker line.

STOCK SHAPES AND SPECIALS

Standard and Zed Electrocast are made in stock shapes and in many special shapes. The weight of individual pieces may run to 3500 pounds.

IF YOU NEED A BETTER REFRACTORY—

● Corhart Electrocast Refractories are high-duty products which have proved considerably more effective than conventional refractories in certain severe services. If your processes contain spots where a better refractory is needed to provide a balanced unit and to reduce frequent repairs, Corhart Electrocast Refractories may possibly be the answer. The brief outline at the left gives some of the basic facts about our products. Further information will be gladly sent you on request.

Corhart Refractories Company, *Incorporated,* Sixteenth and Lee Streets, Louisville 10, Kentucky.

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QUALITY ECONOMY ENDURANCE

CORHART ELECTROCAST REFRACTORIES

and hot-tear test casting in which horizontally cast bars were cast around small insert bolts secured to the molding flask by a nut. The nut could be slackened back to vary the degree of restraint applied to the bar during solidification.

Except for the DTD bar, all the castings were not fully fed, and were designed to study the effects of varying distribution of shrinkage porosity. A few castings were also made in chill molds, which were lowered into molten lead-tin alloys held at a controlled temperature.

It is concluded that (1) the characteristic microporosity in magnesium alloys is due essentially to unfed shrinkage in alloys which solidify over a temperature range; (2) the presence of gas in magnesium-base alloys causes a marked increase in the amount of microporosity in the casting, and does not alter its characteristic form; (3) owing to their low heat capacity and relatively rapid solidification, the temperature distribution in many magnesium alloy castings tends to be less favorable to progressive feeding; and (4) under the same solidification conditions, the strength of unfed castings in magnesium and aluminum alloys is affected to the same extent, but that it is more difficult to ensure correct solidification conditions in magnesium than in aluminum alloys.

—E. A. G. Liddiard & W. A. Baker. *Foundry Trade J.*, Vol. 77, Oct. 25, 1945, pp. 155-161, Nov. 1, 1945, pp. 173-179.

The Roll Hearth Furnace

Condensed from "Stahl und Eisen"

The roll-hearth furnace is a continuous furnace the hearth or bottom of which is formed by rolls which convey the material to be heated through the furnace. The type described is composed of separate units which can be assembled in any desired number to form a furnace of desired length.

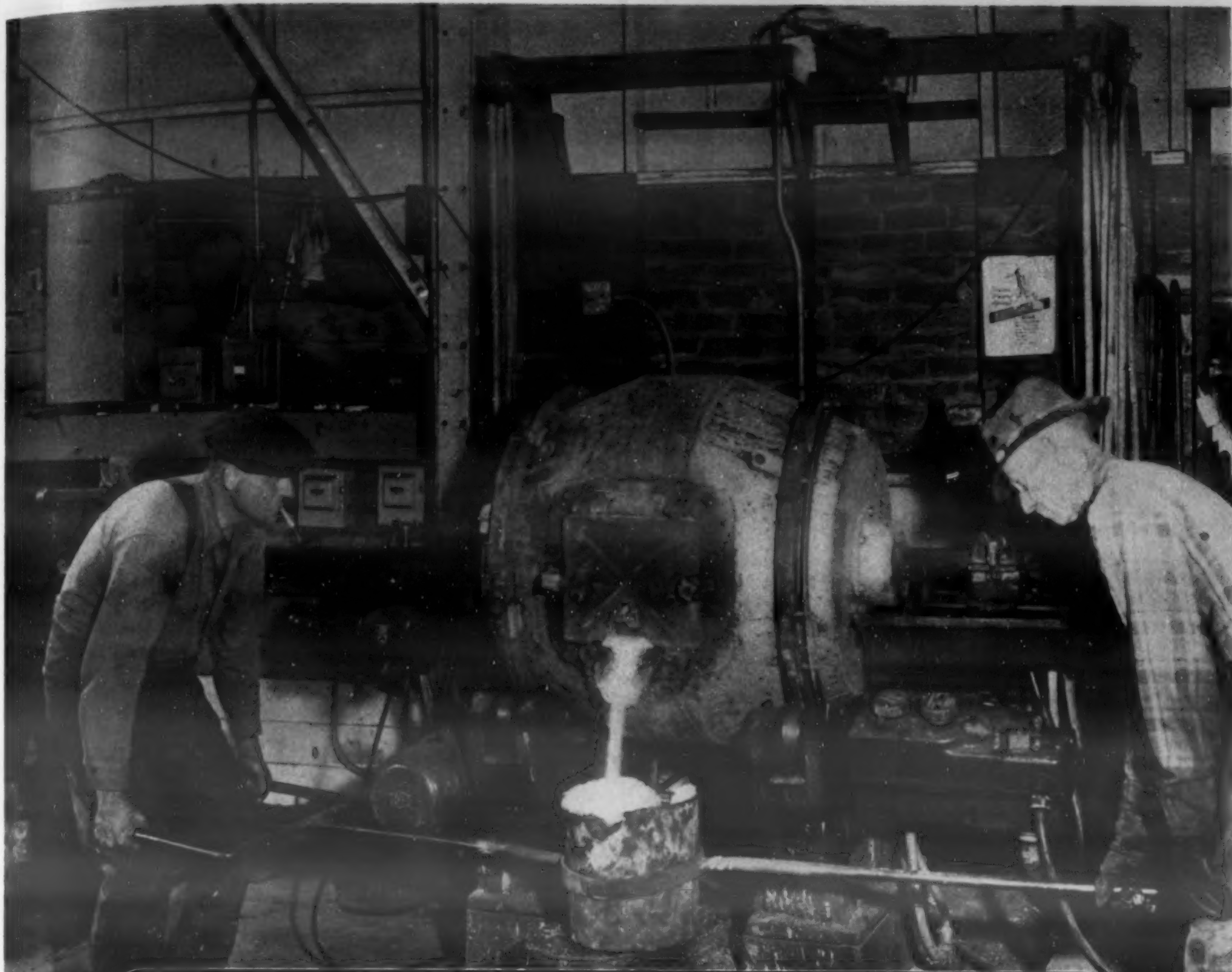
The rolls are made of a core of ordinary steel of 155-mm. diam., protected by a cylinder of heat-resisting material with 185-mm. diam. A furnace with 28 rolls is described in which this heat-resisting material is of steel, with 26% chromium and 14% nickel; each roll is 2.9 m. long and weighs 150 kg.

The bearings with oil lubrication are arranged in the furnace walls; oil consumption amounts to 0.51 lb. per 24 hr. for the 56 bearings. Driving power is 5 h.p. Furnace length is 10 m. inside, with inside height 685 mm.

The lining consists of 250-mm. lightweight brick, insulating layer of 60 mm., and outside steel plates. Gas consumption for 7.5 ton per hr. is 180 cu. m. per hr., or 24 cu. m. per ton; for 6.5 ton per hr., 162 cu. m. per hr. and 24.9 cu. m. per ton. Thermal efficiency is 45% for 7.5 ton per hr.

The furnace is used for heating of slabs and rounds, and for annealing and normalizing of finished sheets. The unit construction of the furnace makes it particularly flexible and useful, as it can be easily transported to any desired place in the plant.

—W. Offenberg. *Stahl u. Eisen*, Vol. 64, Oct. 26, 1944, pp. 679-682.



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For melting Grey Iron, Ni-Hard and Ni-Resist in 350-lb. Type "LFC" Conical DETROIT ELECTRIC FURNACES. The iron being poured when this photograph was taken, the 400th heat from this P. B. SILLIMANITE lining, was used for casting special tubes for oil refineries. Jake Ratzloff, furnace operator, takes pride in getting as many as 500 heats of these iron alloys from P. B. SILLIMANITE linings, with minimum patching. Averaging 12 to 13 heats of 700 to 750 lbs. each in 9 hours.

DETROIT ELECTRIC FURNACES which are lined with P. B. Sillimanite Brick and Special Shapes are setting new records for long, efficient operation and lower refractory costs per ton of metal poured. Lining life may be increased by intelligent patching with one of the P. B. SILLIMANITE Patches and Cements which have been 'engineered' for this job.

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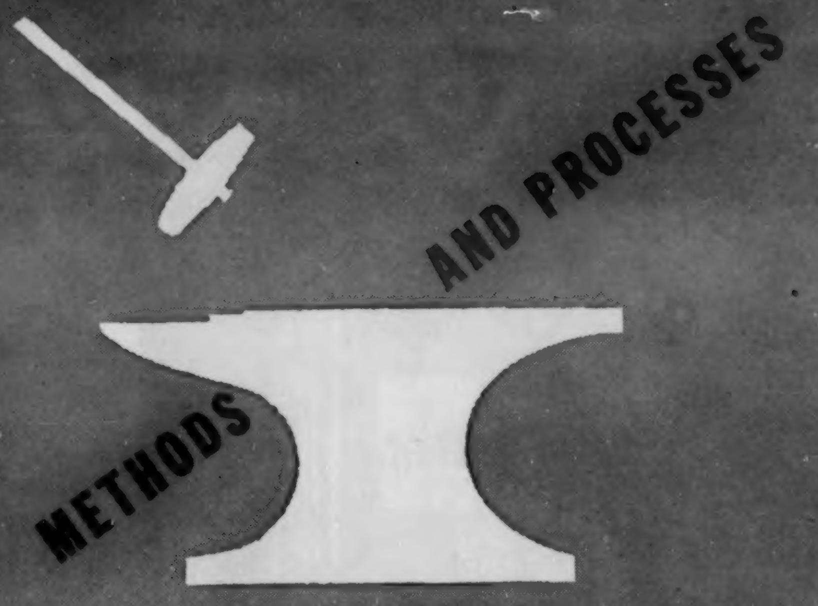

FABRICATION and TREATMENT

Machining, forging, forming, heat treating and heating, welding and joining, cleaning and finishing of solid materials. Methods, equipment, auxiliaries and control instruments for processing metals and nonmetals and for product fabrication.

Templets from Plastic Sheet

Condensed from "Modern Machine Shop"

The use of sheet plastic for tooling purposes helped solve production problems in the fabrication of leading edges for the wings of "Wildcat" Navy fighter planes. Investigation revealed the limits of its dependability and accuracy, and proved its ability to conform to established contours. Further checking revealed that it was relatively unaffected by varying climatic conditions, and that expansion and contraction due to temperature changes was negligible.

Previously, when flat patterns of elliptical surfaces were needed, the "cut and try" method using paper or thin sheet material had to be employed. By using transparent plastic, however, it is possible to draw the material taut around a mock-up and to mark locations and outlines of holes or irregular apertures as they appear through the plastic. Carrying this technique still farther, a complete covering of three separate templets was developed so that when the mock-up skin had been fitted, axes for gun cutouts and inspection holes could also be transferred directly from the rib structure.

Still another advantage of the plastic came to light when the ring surmounting the gun cutout in the leading edge was redesigned. The correct outline was drawn on the leading edge and from this outline a plastic templet was marked off, cut, and the important locations and dimensions transferred to a flat pattern. Using these dimensions, a ring was rolled to the correct contour and checked with the plastic templet.

The plastic sheets used for this work are especially surfaced to take pencil or ink markings, and because of the dimensional stability of the material, the sheets can be used both as drawings and as templets. Blueprints can be made from tracings, and photoprints can just as easily be made from it as from negatives.

A new technique now in process of development will permit the transfer of lines in such a manner that they can be etched, providing permanent markings for cutting or filing templets, dies or fixture elements to exact contours without the necessity of marking off the dimensions and locating points on the material itself.

Both left-handed and right-handed parts can be made from a single drawing by inverting the plastic sheet. The sheet is so thin that no distortion results.

The material used is "Vinylite" plastic, which is available in thicknesses of 0.015 and 0.010 in., and in both platen (clear and smooth on both sides) and calendered (smooth on one side and grained on the other). The 0.015-in. calendered sheet comes in 50 by 144-in. size. In the present instance, the 0.015-in. calendered plastic was used.

For stock wider than 50 in., the usual practice is to fasten sheets together with a 2-in. lap joint, stapling with a Bostitch stapler, and reinforcing with double-faced tape.

To develop patterns for "skins" for aircraft or other similar fabrication, it is suggested that holes and openings be drilled first in the skeleton assemble. Distortion of the sheet plastic is negligible at room temperature. It should be handled carefully to prevent cracking, especially when cold. In storing, it is recommended that the material be kept flat and stored to prevent distortion.

—Phil Glanzer. *Modern Machine Shop*, Vol. 18, Dec. 1945, pp. 192, 194, 196, 198, 200, 202.

Stretch-Forming with Impact

Condensed from "Aviation"

Mass production and close tolerances have revealed the need for stretch forming many parts that had been troublesome on rolls, hydraulic presses and hammers. The Long Beach plant of Douglas Aircraft Co. found novel uses for stretch forming on

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If wages and distribution costs are to remain high, the only way you can keep prices low enough to create new customers (without affecting profits) is to increase production . . . lowering costs, attracting greater quantity and frequency of buying, making new jobs, giving business an adequate return on investment.

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for example: SEE HOW THE BULLARD MAN-AU-TROL VERTICAL TURRET LATHE LOWERS UNIT PRODUCTION COSTS

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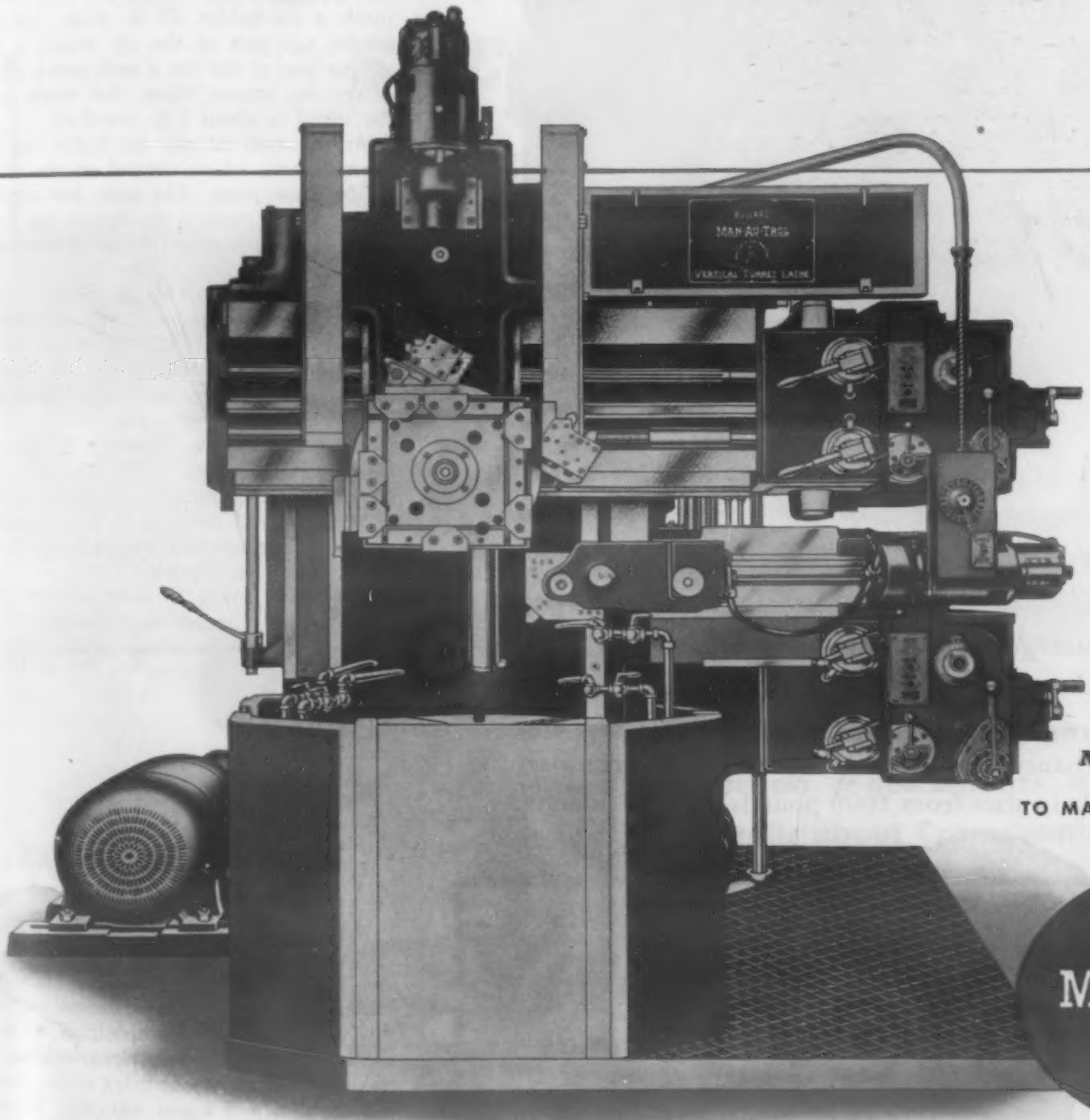
SAVES SET-UP TIME — Set-up time from one class of work to another is only slightly more than for a manually-operated machine.

REDUCES SALVAGE COST — Machines day after day with consistent accuracy not obtained under manual operation.



BULLARD CREATES
NEW METHODS
TO MAKE MACHINES DO MORE

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the A-26 Invader, particularly on bulkhead caps and panel stiffeners of the wing. Such forming has revealed a new type of stretch—an operation that combines impact with stretching.

"Hats" carried a great portion of the wing load, varying in length from 28 in. to 45 in., all 1¼ in. high. They were roll-formed of 24ST Alclad with thickness varying from 0.032 to 0.091 in. All contouring had to be done in SW condition. A joggle 2½ in. from each end must be held to a tolerance of ±0.010.

Making these parts on a stamping machine had been unsatisfactory because they could not be held to proper tolerances. But parts under 20 in. long had been satisfactory because less error accumulated where there were no multiple joggles nor flattened areas.

The short hats would remain on the hammers but the C-flanges on the long formers could never be reformed by the direct impact of a male punch. Solution came with the development of a stretch die with a male punch and jaws that operated under the single action of a Toledo draw press.

An orthodox stretch form die is used, in which a hat section is set with the crown inverted and with the flanges on the upper side of the die. The die reposes inside a die holder, 60 in. long. Fastened in the top part of the die holder is the mating part of the die, a male punch which delays its impact upon the work until the metal is about 5% stretched.

At the ends of the die holder are ingenious jaws, which depend on the action of the draw press. The male jaw encloses the work and contacts the female jaw about 1 sec. before the main impact of the major male punch.

The jaws are locked before the major punch impact, thus providing the stretch action. The Toledo 795½ triple action press is used only because it is sufficiently large and strong for the work. With the rise of the punch, the jaws retire only a fraction of the travel distance before they disengage the work. By this time the part has been stretched while the major impact has been made to form the joggles, set the bevels, contour the part and flatten C-flanges where required.

The outfit has a capacity of 950 parts per day. All dies are of Kirksite.

—Douglas Hodges. *Aviation*, Vol. 44, Nov. 1945, pp. 147-119.

Welding 18:8 Stainless Steel

Condensed from "The Welding Journal"

Since a marked heat-to-heat variation in the weldability of stabilized 18:8 was found, an attempt was made to correlate this weldability with composition. Most of the tests were on oxyacetylene welding, although some were made using atomic hydrogen, helium and argon welding. A weldability rating was set up on the basis of the net production per 8-hr. day by a welder of better than average ability.

The most important element as far as effect upon oxyacetylene weldability is concerned is silicon. Manganese and titanium seem to have a lesser effect, and the other elements have practically no effect at all in their usual ranges. The weldability improves with increasing silicon and manganese. Therefore, Solar Aircraft Co. intend to specify a minimum silicon content of 0.50% and possibly minimums of 0.60% silicon and 1.25% manganese for stabilized stainless steel to ensure an increase in the average weldability index. These limits will not affect the forming properties of the steel.

The atomic hydrogen welding tests showed also that a minimum of 0.50% silicon is necessary for satisfactory welding properties. In helium and argon shielded arc welding, very little or no correlation was found between weldability and chemical composition except where burned tack welds existed. It was found that they could be picked up much more easily on the samples with 0.50% silicon or more.

If the silicon and manganese contents are above 0.50% and 1.25%, respectively, there is very little to choose between Types 321 and 347 with respect to welding properties.

It is assumed that the extreme effectiveness of silicon in decreasing the amount of gas trouble encountered may be due to its action as a deoxidizer and slagging element which prevents these oxides from reaction with carbon to form carbon monoxide. It is believed that possibly part of the beneficial effect of manganese is an alternation in the form of the slag to enable the gas to be more readily eliminated.

—F. H. Page, Jr. *Welding J.*, Vol. 24, Oct. 1945, pp. 929-932.

Aging Aluminum Alloy Rivets

Condensed from a Paper of the National Advisory Committee for Aeronautics

Aluminum alloys used for high strength rivets are of the duralumin type, containing copper and magnesium, and usually manganese, or of the magnesium-silicide type, containing magnesium, silicon, and chromium. Alloys of the first type are aged at room temperature, those of the second at higher temperatures.

Magnesium-silicide alloys may be driven cold in any condition, while the duralumin alloys of high strength must be driven immediately after solution heat treatment to avoid danger of cracking. The more workable of the duralumins may be driven cold.

To study the effects of aging, three alloys of the duralumin type, 24S, 17S, and A17S, and one of the manganese-silicide type, 53S, were tested in shear in riveted sheets. The ratio of shearing strength to tensile strength (of undeformed wire) remained constant, independent of aging time at room temperature. The ratio varied from 0.60 to 0.70, the higher the tensile strength the lower the ratio.

Aging times at room temperature required for each alloy to reach practically its final strength value were: 24S, 7 hr.; 17S,

(*Continued on page 517*)

3 days; A17S, 8 mo., 53S, more than 2½ yr. Aging times at room temperature required for rivets driven before aging to reach practically their final strengths were: 24S, 3 mo.; 17S, 1½ yr.; A17S and 53S, more than 2½ yr.

The immediate effect of the cold work involved in driving the rivets was sometimes an increase, sometimes a decrease. The effect on subsequent aging of this cold work was in all cases a retardation, except only that there was no incubation period for 17S rivets driven before aging. For a given total aging time after quenching rivets driven after aging were always stronger than those driven before.

Precipitation heat treatment of alloys 53S had to be carried out immediately after quenching to obtain maximum strength values. No further aging of this alloy occurred after precipitation heat treatment. The strength of a 53S-T rivet after precipitation heat treatment was about the same as that of a 17S rivet immediately after quenching, or of a freshly driven A17S rivet driven after aging 1 day.

The driving stress required for a 53S-T rivet was about the same as that for an A17S-T rivet driven after aging 4 or 5 hr.

—Frederick C. Roop. Paper, *Nat. Advisory Committee for Aeronautics*, Report No. 724. 1941.

Hard Chromium Plating of Cutting Tools

Condensed from "Z. Ver deut. Ing."

An investigation was carried out to find whether the cutting capacity of cutting tool edges can be improved by hard chromium-plating and the best conditions of plating and, in particular, which tool steels are best suited for this type of plating.

Two types of plating baths were used:

	Bath I	*Bath II*
Bath concentration	300 g. CrO_3 per l.	300 g. CrO_3 per l.
Other acid addition	sulfuric acid	mixture of hydrofluoric and silico-hydrofluoric acid according to DRP 710694
Amount of addition	1% of the CrO_3 content	
Chromic bath temperature	50 C.	for both baths
Current density	40 amp. per sq. dm.	

Chromium layers of 10 and 50 microns thickness were used. The material used was (1) rapid steel of group ABC II with 10% tungsten, 1.7% vanadium, 0.6% molybdenum, 0.8% carbon; (2) tool steel with 1.2% chromium, 1.1% carbon; and (3) for comparison, hard metal of group G1. Only the edges were chromiumplated.

The tests determined the life when the tool was predominantly stressed by temperature (heating), predominantly by wear, thickness of cut, influence on shape of chip by properties of tool material, and influence on obtainable surface quality by tool material properties. A brief résumé of

the results can only be given; they are shown in numerous diagrams and photographs.

The hardness of the chromium layers depends on temperature; while at normal temperature it is 750 to 800 Brinell units, it is at 400 C (750 F) only ½ to ⅔ of the original value, so that it has lost its cutting ability. Chromiumplated tools can therefore stand temperatures of more than 400 C only for a very short time; for practical service, the chromium layers should not be exposed to more than 300 to 350 C (570 to 660 F).

Material which can be cut within these temperature limits at speeds up to 200 m. per min. (650 ft. per min.) are synthetic materials, brass, zinc alloys and such non-ferrous metals the cutting temperature of which does not exceed 350 C even at higher speeds.

Cutting of steel and cast iron is possible at low cutting speeds, but the present test results do not justify the fairly expensive chromiumplating as the obtainable advantage is not so considerable. Cutting conditions should be kept so that the temperatures mentioned are not exceeded.

The specific cutting forces should not exceed 200 to 250 kg. per sq. mm. as otherwise the chromium layers might be crushed off or spall off. Steel and cast or not at all, only the before mentioned iron can hereby not be cut advantageously group of materials.

If the temperature conditions are observed, wear only determines the life of the chromiumplated tool. A layer of 50 micron thickness is preferable for non-ferrous metals and synthetic materials. Thicker layers are not recommended. The specific cutting force increases with increasing cutting time, but considerably less than for steels not chromiumplated.

The surface quality (roughness) is better with chromiumplated tools. The plating of the edges must be very uniform and smooth; if they are rough, dull and show little beads at the edges, or if they have been damaged in grinding after plating, the deposits are liable to come off.

—H. Schallbroch & W. Hielscher. *Z. Ver. deut. Ing.*, Vol. 88, June 10, 1944, pp. 321-326.

Brazing Carbide Tips

Condensed from "Western Machinery & Steel World"

Attaching cemented carbide tips to cutter bodies is accomplished by two general methods—mechanical clamping and brazing. Of the large number of methods for brazing, only three are in general use for attaching carbide tips to cutter bodies or shanks: Gas or acetylene torch brazing, furnace brazing, and the use of the high frequency induction electric current to supply the heat.

The acetylene torch, mainly because of the low first cost, is the most common method. It is important to remember the following:

(1) Use a neutral to reducing flame.
(2) Heat work above flow point of brazing

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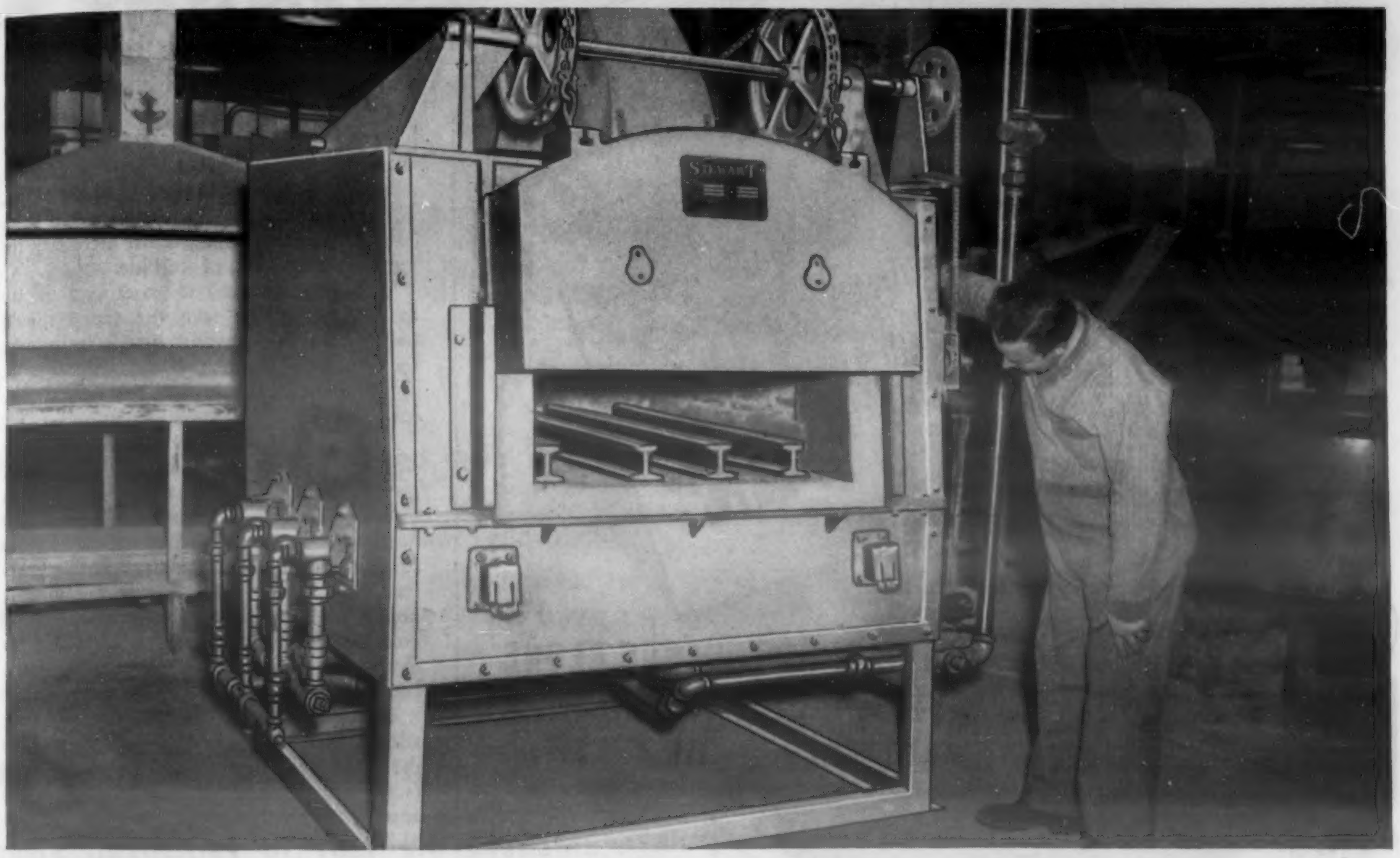

For baking out the core molds of Tantung cutting tools, perfected by Fansteel to fill the gap between conventional high-speed steel tools and cemented carbides, the Fansteel Metallurgical Corporation, North Chicago, uses two large Stewart gas-fired Oven Type Furnaces, illustrated above. This Corporation specializes in the production of Tantalum, Tungsten, Molybdenum and Columbium rare metals and parts and products made from them.

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alloy. (3) Allow heat of shank on cutter body to supply necessary heat to melt brazing alloy as well as heat the carbide tip. (4) Avoid direct impingement of flame upon the brazing alloy or carbide tip. (5) Heat shank and tip uniformly. (6) Apply pressure to tip. This holds the tip in place while the brazing alloy is cooling and forces out any excess that might accumulate between the tip and shank.

Furnace brazing requires a furnace in which the atmosphere within is under control to prevent oxidation. Cooling must be controlled to prevent cracks in the carbide, warpage of the cutter body and oxidation of the machined surfaces. The work and furnace should be brought up to temperature slowly and evenly for best results, otherwise cracks will occur in the carbide.

It has been found that tips can be brazed in 7 to 10 sec., but this speed usually results in cracks in the carbide; also, the quality of the brazed joint is very uncertain. It has been found that if from 1 to 1½ min. are consumed in the heating, no cracks will occur and the joint will hold. This longer time is especially necessary for the harder grades of carbide.

The design of coil to go around the tip to direct the heat into the shank should be so that the heating occurs uniformly, starting away from the tip a distance of approximately ½ in. and then traveling toward the tip.

Brazing with silver solders is relatively simple. The carbide surfaces should be ground lightly to remove dirt and foreign matter. Thorough cleaning is absolutely necessary. During pre-heating, protect the surfaces from oxidation by using a flux that will liquefy at or below the melting point of the brazing alloy and be readily volatilized. The flux protects surfaces from oxidation, dissolves oxides as they form, and assists the flow of the brazing alloy.

It has been found that the silver brazing alloy which flows at 1175 F, used with the proper flux, produces the most satisfactory joint. The brazing alloy may be applied as thin sheets, flat washers, rings of round wire, filed or powdered alloys, or it may be sprayed on or applied by dipping.

The surface of the cutter to which the carbide is to be brazed must be flat and fairly smooth. The only argument in favor of embedding the carbide into the cutter body is appearance. To prevent grinding cracks, it is recommended that brazing only under the tips is preferable.

—R. O. Catland. *Western Machinery & Steel World*, Vol. 36, Nov. 1945, pp. 486-492.

Spot Welding Lead

Condensed from "Product Engineering"

Lead, lead alloys and terneplate can be spot welded with 60 cycle a.c. if the time, current and pressure are accurately controlled. The low melting point and compressive strength of lead and its alloys necessitate a low heat input and electrode pressure to reduce indentation. An electrode tip with a 0.2-in. flat end and a body diameter not less than twice the weld diameter is satisfactory.


DEPENDABLE SUPPLY

Unequal sheet thicknesses or currents over 185,000 amp. per sq. in. may cause surface melting. The optimum pressure is 41 to 46% of the tensile strength for lead alloy sheets and 100% for lead sheet. If the pressure is too high, plastic flow will result with no fusion in the center of the weld. If it is too low, surface melting will result.

The best welding time is over 30 cycles for sheet over 0.15-in. thick; lighter sheets were welded satisfactorily with shorter times. Secondary voltages of 4.0 to 6.3 v. were used. Slight variations in current over a narrow range may either reduce the weld size considerably or cause excessive expulsion of the molten metal.

If the thickness of a single sheet in in. = t, then the best welding conditions are approximately: Pressure in lb. = 12,000 t^2 + 50; time cycles = 137 t + 420 t^2; secondary current in amp. = 80,000 t^2 + 5500. Spot welds of commercially pure lead are ductile but weak, while the spot welds of lead antimony alloys are stronger but less ductile.

When lead and lead alloys are spot welded to terneplate, the tips must be modified to cause a concentration of the heat on the terne side. Heavily coated terneplate is best. A direct bond between lead and uncoated steel is not possible, but spot welds can be made if an intermediate layer of terneplate is used.

The pressure depends on the thickness of the terneplate and is independent of the composition or thickness of the lead or lead alloy. The optimum time varies both with the thickness of the lead and the thickness of the terneplate.

The low shear strength of the welds is not an indication of brittleness and is good relative to the strength of the lead. The smaller weld sizes give the higher ratio between the shear strength and the tensile strength.

—J. Heuschkel. *Prod. Engineering*, Vol. 16, Dec. 1945, pp. 872-876.

Processing Stainless Steel

Condensed from "Steel Processing"

Virtually all types of chromium-nickel stainless steels for sheet and plate applications contain low carbon. The grades that are mainly used for such applications are American Iron & Steel Institute types 301, 302, 304, 308, 309, 310, 316, 321, and 347, and an 18-12 alloy containing 1.50 to 2.50% molybdenum and 0.50 to 0.80% columbium.

All these grades have austenitic structures in the annealed condition. Those alloys containing columbium, titanium, or somewhat higher carbon have carbide particles dispersed in the structures. Cold working will cause strain lines.

Precipitation of chromium carbides in the grain boundaries and within the grains must be avoided under any condition, as this has a very unfavorable effect on corrosion resistance. This can be prevented by using a very low carbon alloy (which has unfavorable features), avoiding ex-

posure at 1000 to 1700 F, or using grades containing columbium or titanium and stabilizing them. Precipitated carbides can be redissolved by heat treating at 1850 to 2050 F.

Annealed material has high strength and very high elongation and ductility. All the grades work harden.

Conventional furnaces are well suited for heat treating, but they must be designed for temperatures up to 2050 F. They may be fired by oil or gas or electrically heated. Salt-baths are also satisfactory. Uniform heating, soaking, and cooling are absolutely essential. Continuous operation is preferable to batch operation. Generally, the material must be cooled as rapidly as possible, forced air cooling being preferable.

Oxidizing atmospheres should be used. Mildly reducing conditions are not detrimental, but strongly reduced atmospheres should be avoided. Direct flame impingement is very harmful. Sulphur content of the atmosphere must be as low as possible.

Before heating, the surface of the material must be cleaned thoroughly. In full annealing, the steels are heated to desired temperatures at a reasonably rapid rate, soaked for a short time, and cooled very rapidly. The temperatures are 1950 to 2000 F for grades 301 and 302; 1925 to 1975 F for 304, 308, and 316; 1900 to 1950 F for 321, 347, and 18-12 with molybdenum and columbium; and 2000 to 2050 F for 309 and 310.

Process-annealing procedure is basically that of full annealing, except for somewhat lower temperatures and shorter cycles.

Stabilizing of grades containing columbium or titanium is done by heating at 1600 F and cooling in still air. Stress relieving of cold-deformed material is carried out by heating to 500 to 800 F for ½ to 1 hr. and cooling in the oven or in air.

—H. S. Schaufus & W. H. Braun. *Steel Processing*, Vol. 31, Oct. 1945, pp. 625-629; Nov. 1945, pp. 691-696.

Hot Stretch-Forming

Condensed from "American Machinist"

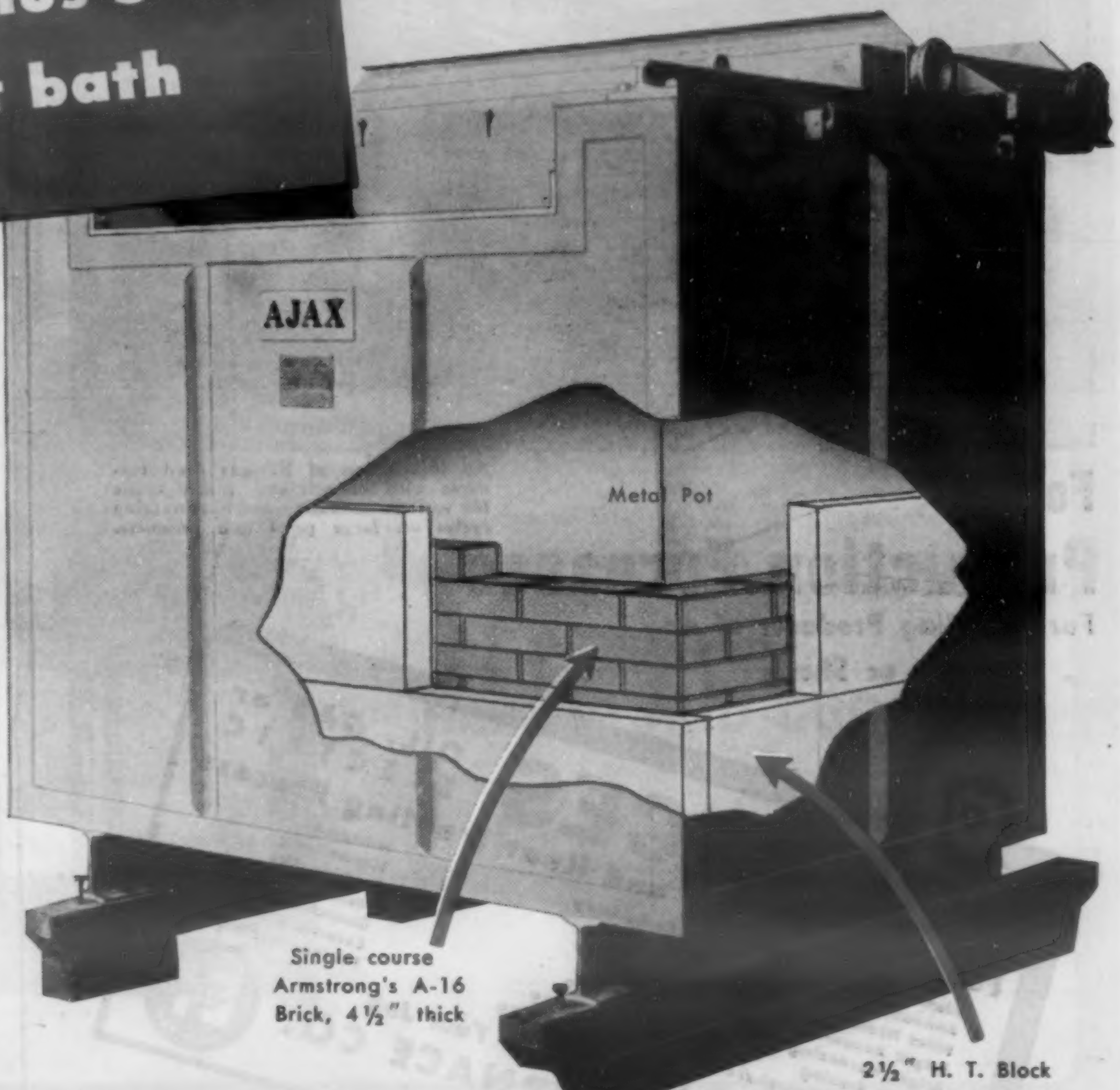
Forming limits of certain aluminum alloys at high temperature and under combined tension and bending can be improved only by close control of prestretch forming speed and temperature. For plant testing, "U" sections were used as they duplicated commercial parts. Here there is no localized cold-worked portion from preforming. The section was formed with the web on the outside. Sheet alloys, 24SO, bare and clad, and 24ST were tested.

The section was preformed from 0.040 by 20 in. long sheet to a ½-in. radius on a brake press. Strips of various widths were cut with the grain from a single sheet. Prior to preforming, a 20-line per in. orthogonal grid was printed parallel to the transverse and longitudinal directions of the sheet.

The Roto-Stretcher, used for curving the sections, was a stationary bench through which a gear-driven shaft extended to rotate a platen. A pneumatically-operated zinc alloy jaw, with knurled holding surfaces,

Plus or minus 5° F. in a salt bath

Insulation of electrically heated salt bath furnace made by Ajax Electric Company, Philadelphia, Pa.



How Armstrong's Insulating Fire Brick help maintain exact heat treating temperatures

STEADILY MAINTAINED TEMPERATURES in salt bath furnaces mean faster, more uniform heat treating of metals. But, to prevent temperature variations, hot spots or cold areas in the bath must be avoided. This requires not only proper design and placement of heating elements but also the right insulation.

There are two important reasons why Armstrong's Insulating Fire Brick permit easy thermostatic control of salt bath temperatures to plus or minus 5° F. One is low thermal conductivity; the other is accurate sizing. The low thermal conductivity of these brick, which prevents excessive heat loss through furnace walls, has been established by tests and by thousands of successful installations. The accurate, uniform sizing of Armstrong's Insulating Fire Brick makes possible snug, heat-tight joints in furnace construction.

All five of Armstrong's Insulating Fire Brick, for temperatures from 1600° to 2600° F., have high insulating efficiency, low heat storage, high resistance to spalling, great strength, and light weight. These qualities are more important than ever in the new high-temperature processes being developed today. Armstrong's engineers will gladly help in the solution of your furnace problems, without obligation. For full information write today to Armstrong Cork Company, Insulating Refractories Dept., 5502 Mulberry St., Lancaster, Pa.

ARMSTRONG'S INSULATING REFRACTORIES

was clamped to the platen. The second jaw was attached to a 14-in. stroke hydraulic piston which maintained a constant stretching force by balanced relief valves and a manual speed control.

Pressure in the cylinder applying the stretching force was indicated by a dial gage. The forming die was bolted to an electric element heating platen resting on a transite pad, insulating it from the revolving platen to which it was attached.

The polished die was heated by conduction from the heated platen, controlled by a plus or minus 10 F thermoswitch. The steel block had electric heating elements, temperature being controlled the same as the die. The ends of the section to be curved were placed in the clamp jaws and air pressure applied.

The specimen sometimes failed immediately upon again starting to rotate the die (bend) after a pause during which the stretching force was usually increased, or might occur during rotation of the die and curving of the section.

At room temperature "necking" occurred in both 24SO and 24ST at about the uniform elongation of 18%, which was observed in a tensile test. It appears that greatest maximum (constant) strain can be obtained only through a careful balance of the prestretch (applied tension), the rate of progressive forming which must be fast enough to prevent failure by creep, and the forming temperature which must be uniform at all points along the specimen. The effects of friction on formability of annealed alloys are important.

—George Sachs, George Espey & W. F. Brown. *Am. Machinist*, Vol. 89, Dec. 6, 1945, pp. 98-100.

Resistance Welding Enameling Stock

Condensed from "Finish"

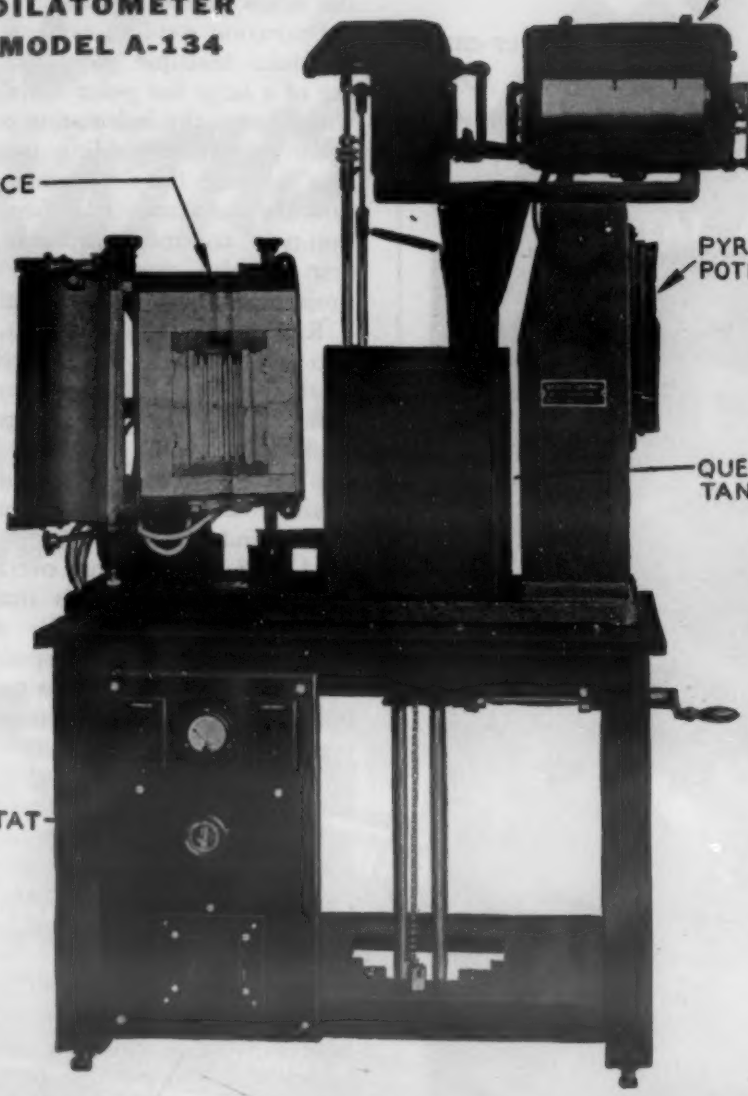
The subject of resistance welding prior to porcelain enameling is divided into spot, projection, roll seam, and flash-butt welding. As far as the application of spot welding is concerned, the problem is the same as that confronting the user of the process for fabrication requiring high strength and good appearance. This necessitates equipment capable of providing the proper current pressure and timing value.

Formerly, evidence of heat on the surface of a spot weld was demanded. Today such a weld is no good. In fact, spot welds are made in light gages which show practically no heat on the outside surfaces and no indentation except a slight heat shrink.

Cleanliness is, of course, the basic requirement for a good weld. Unclean surfaces will result in "spits," small red-hot particles that explode out from between the faying surfaces and cause rough specks wherever they hit and stick. The spot will show a depression and the opening between the faying surfaces will be a place for the pickle solution to lodge and then boil out under the enameling temperature.

It is necessary to use mechanically or air operated machines and weld timers and contactors. Another point worth remembering is the center distance on welds. A

BRISTOL-ROCKWELL DILATOMETER MODEL A-134



HOW METAL ACTS *when* HEATED AND COOLED

...Charted on Paper

You can get four important types of information about temperature effects on metal—easily and accurately—from the improved model of the Bristol-Rockwell Dilatometer:

- **Critical points of carbon steel**
- **Coefficients of expansion**
- **Composition (from thermal curves)**
- **Heating rates and heat saturation**

Temperature-dilatation and temperature-time changes are recorded simultaneously during heating and cooling cycles.

The built-in electrical furnace (rheostat-controlled) heats to 2500°F. It takes samples up to 5″ x 1⅝″ (best sample sizes: 2½″ to 3½″ long). Ferrous and non-ferrous metals can be tested.

Quenching Tank

An added feature is the quenching tank which can be raised to the quench position without moving the sample or interfering with the dilatation measuring system.

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good rule to follow is that on 16 gage and 14 gage material thickness: ¾ in. C/C distance is minimum. On 20 gage, ½ in C/C distance can be used, but ¾ in. is preferred. The edge of the spot should be at least one gage thickness away from the edges of the material.

Projection welding presents the best way to make multiple welds, and allows the use of a large flat point against one surface, which keeps the indentation to a minimum. Since projection welding is a variation of spot welding, the requirements for preparation are the same. It is best to use pulsation-type control equipment so that the first impulse evens off the tops of the projections and brings them all into contact.

Roll seam welding or stitch welding is also fundamentally a spot welding process. Normally, one edge is lapped over the other. They are first pre-spot-tacked and then seam welded at upwards of 150 in. per min. When seam welding for porcelain enameling, the lap must be eliminated and the mash type of the seam weld used. The normal overlap is reduced and the spot tack welds should be much closer and more carefully made. When mash seam welding, the speed of the weld wheel cannot be as great as regular speeds—60 in. per min. is maximum with safety even on 20 gage.

As far as control equipment required for mash seam welding is concerned, an ordinary tube contactor and heat control is satisfactory because no current interruptions are required beyond the natural interruption that occurs 120 times a sec. on 60-cycle current.

Flash-butt seam welding is basically a different operation because the material is edge to edge. The most important thing to watch is the possible formation of gaseous pockets and subsequent bubbling. This has to do with the secondary voltage during the flashing operation. This voltage should be kept as low as possible.

The removal of the flash and upset deposit from a flash weld can now be trimmed within 0.002 in. of the surface with a shaper tool. The grinder or air chisel are satisfactory alternates.

—C. G. Bassler. *Finish*, Vol. 2, Dec. 1945, pp. 19-21, 52.

Recrystallization in Cold-Rolled Brass

Condensed from "The University of Illinois Engineering Experiment Station Bulletin"

Because of the role played in fabrication of the metal, recrystallization of cold-worked brass is of great industrial importance. Failure to distinguish between grain size due to recrystallization and that due to coalescence subsequent to recrystallization, has made much of the data assembled heretofore of limited value.

Three variables, degree of cold deformation, temperature of the anneal, and time of anneal, exist. The third has usually been made constant, causing erroneous data, since the grain size produced is then not necessarily due to recrystallization alone, but to coalescence following recrystallization also.

Bars of cartridge brass were heated to about 730 C (1340 F), hot rolled according to a definite schedule, cooled, and cold rolled. After an annealing schedule, the bars were cold-rolled to final size, and grain size was measured.

Grain size at just complete recrystallization was independent of time and temperature, and depended upon composition and treatment of the metal prior to deformation. The grains in the solid state may grow at the expense of cold-deformed metal (recrystallization) or at the expense of unstrained metal (coalescence).

There seems to be no germinant temperature for abnormally large grains, since increase in temperature for a given cold-work and annealing time produces coarser rather than finer grain. Decrease in the degree of cold-work produces coarser grains in the just completely recrystallized metal.

Regardless of whether growth be at the expense of cold-worked metal or of newly formed and unstrained grains, grain size increases with time and temperature and obeys the laws of normal grain growth. The same laws account for all instances of growth and production of large grains. The number of nuclei that serve as recrystallization centers is independent of temperature, but is dependent upon degree of cold-work.

Velocity of grain growth by coalescence is lowered with decreased temperature of annealing for recrystallization. The lower the temperature of annealing the longer the time required for recrystallization. For a given percentage of cold-work the coalesced grain size is more easily controlled the lower the annealing temperature.

—H. L. Walker. *Univ. Illinois Engineering Experiment Station Bull.*, Vol. 43, Nov. 23, 1945, 58 pp.

Heat Treating Alloy Steels

Condensed from "Metal Treatment"

The success of annealing and heat treating depends upon the furnace operators carrying out their instructions. In England, batch-type furnaces are generally used with electric furnaces for the lower temperatures and city gas or producer gas furnaces for the higher temperatures. The temperature is automatically controlled and recorded.

A progress and planning department is necessary to give accurate instructions to the shop and to plan the flow of material. Remakes curtail efficiency and must be avoided if at all possible. If a grade has been found to give variable results, samples of each heat should be sent to the laboratory for routine tests and Jominy results before the steel from that heat is sent to the shop for heat treating. The optimum charge weight is very important and is best determined by test.

It has been found best to specify the total time in the furnace rather than the time at temperature to eliminate the personal factor and to allow the foreman to work to a planned production. The technical controller should not only specify

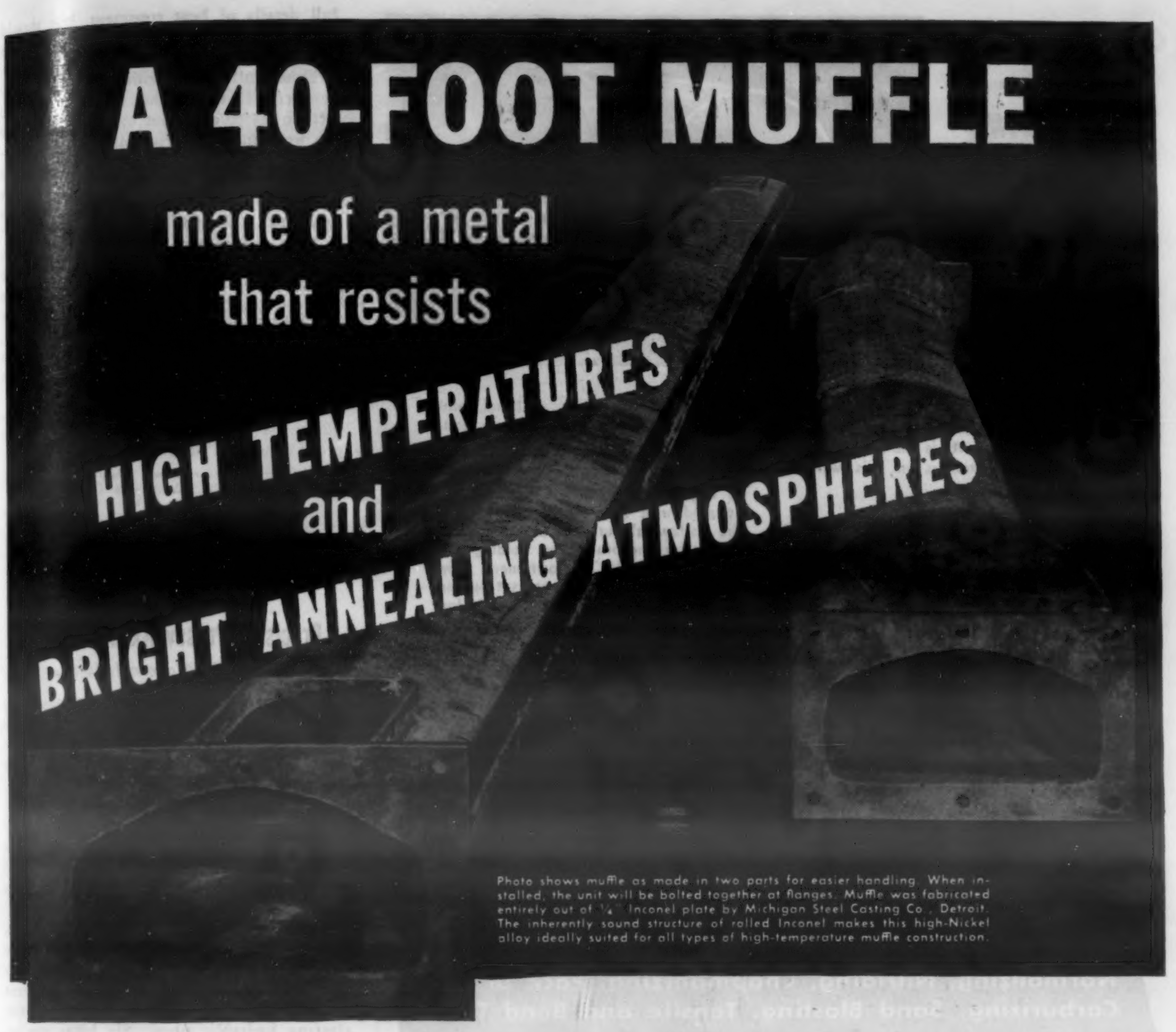


Photo shows muffle as made in two parts for easier handling. When installed, the unit will be bolted together at flanges. Muffle was fabricated entirely out of ¼" Inconel plate by Michigan Steel Casting Co., Detroit. The inherently sound structure of rolled Inconel makes this high-Nickel alloy ideally suited for all types of high-temperature muffle construction.

When this "king-size" muffle is installed in the plant of W. M. Chace, Detroit, it will be used in the bright annealing of bi-metal and alloy strip.

It will have to stand temperatures up to 1850° F...

It will have to resist the embrittling effect of dissociated ammonia...

...and it will!

For this muffle is made entirely of Inconel*.

Inconel is an 80 Nickel-14 Chromium alloy developed specially for high-temperature duty. It is strong, and retains its strength at high temperatures. It resists embrittlement by hydrogen. It does not scale away through oxidation. It resists practically all the corrosive atmospheres encountered in heat-treating operations.

Investigate Inconel whenever you need a sound, rolled metal offering resistance to heat... stress... oxidation... corrosion. It's a thermally durable metal that's available in all common mill forms.

If you want to learn how Inconel performs, just ask one of your friends who has already used this INCO Nickel Alloy... or, send for, *"For Long Life at High Temperatures."*

*Reg. U. S. Pat. Off.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall Street, New York 5, N. Y.

INCONEL ...for long life at high temperatures

(80 NICKEL-14 CHROMIUM)

full details of heat treatment, but should also stipulate the actual furnaces to be used for each operation.

Either full or sub-critical annealing may be used. If the former is planned, it is well to try to carry out this operation over the week-end to save as much actual working time as possible. In full annealing, it is not advisable to aim for the highest possible efficiency, as any miscalculation will mean a long re-anneal.

Most annealing is sub-critical. The weight of steel being treated in a single furnace does not need to be controlled as carefully for sub-critical annealing as for heat treating. If steels are hard to soften, a slow, controlled rate of heating through the last 90 F may eliminate a long soak at temperature.

Electric furnaces have been found to require less attention and to be more fool proof than gas fired furnaces.

—Q. C. McMillan. *Metal Treatment*, Vol. 12, Autumn 1945, pp. 177-182.

Precision Presswork in Assembly

Condensed from "Modern Industrial Press"

In the Ford-Ferguson tractor an unusually heavy load on the power transmission calls for precision manufacture of the axle assembly. Parts and sub-assemblies reach the production line at a specified time.

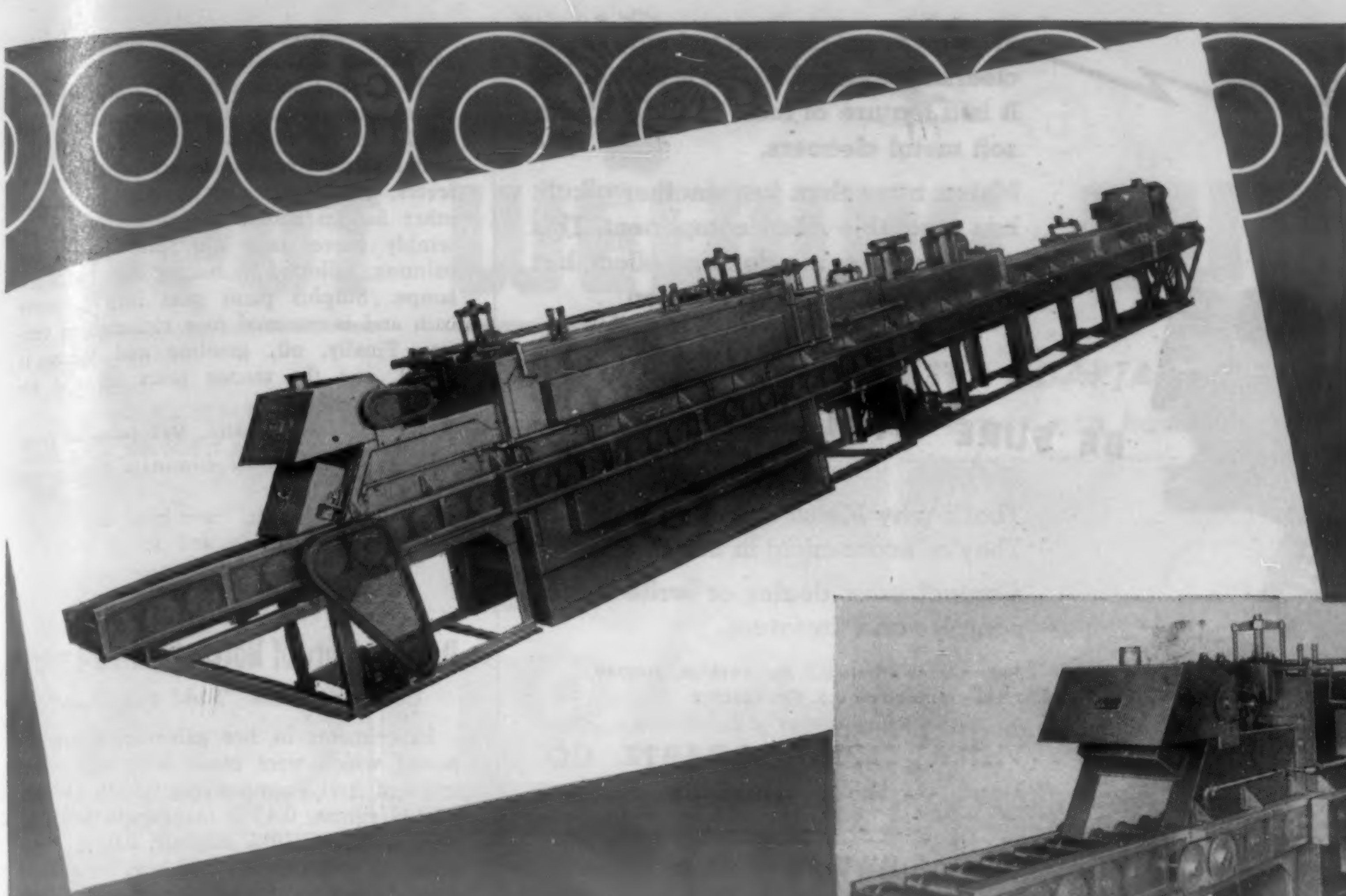
The main assembly line is in four sections to provide greater production flexibility. The axle sections remain the basic units. They are complete with splined shaft, riveted plate, and machined to within thousandths of an in.

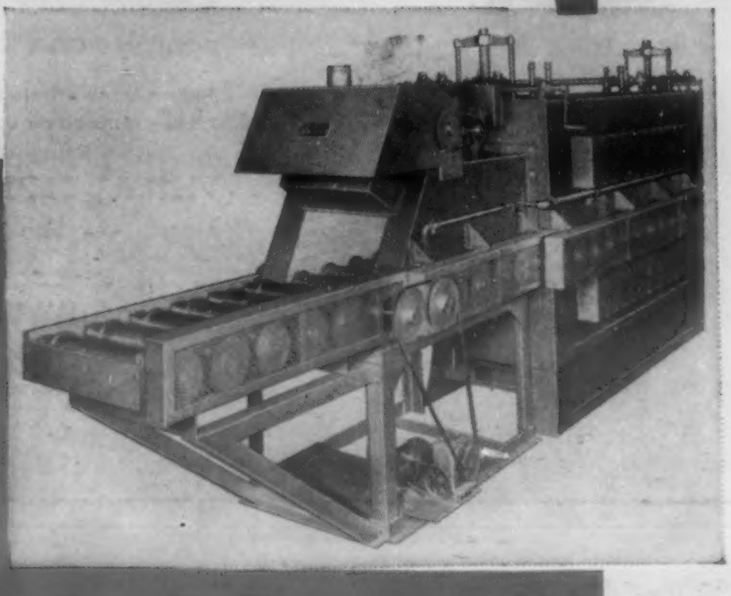
The first operation is to swage six 2-in. notched bolts into the outer rim of the axle and brakedrum. One side of the head of the bolts is cut away to prevent turning after they are swaged in a 500-ton clearing hydraulic press. Six bolts are set by hand in the outer rim. Once in place, the work is placed on a fixture and thence is largely automatic.

The operator grasps the spline end of the axle and tilts the whole assembly towards him, providing a circular, wheel-like section to assist him as he rolls it toward the press area. Gravity delivers several parts for the assembly, such as the rims which fit about the outer circumference of the base plate. In the final stage of tractor assembly, batteries are fed to the installers on a slanted runway, and likewise with tires and rims.

To insure a close fit of the ring in the bearing assembly, it is heated on an electronic unit and pressed into place. A hand-operated arbor press forces a circular dust shield firmly against the rim or drum of the axle. Housings are installed and the sections move to the automatic grinders. Special gages constantly check on dimensions.

Moved by overhead hoists, the axle sections are affixed to the center housing section by studs and bolts. A gear assembly which activates the wheels is fitted into place. With a forcing bar the gear assembly is slipped snugly into place. The axle sections are bolted into place and the





THE LINDBERG *Roller Hearth* FURNACE

Brazes Heavy Loads Efficiently by Continuous Production

Designed to handle economically work too heavy for mesh belt types, the Lindberg Roller Hearth Continuous Production Brazing Furnace accommodates loads up to 2500 net pounds per hour.

With an effective temperature range from 1300°F. to 2500°F., this furnace does bright annealing, low temperature silver brazing and sintering of powder metals. A variable speed drive and special input control meet the heating requirements of each. A selection of controlled atmospheres is available to handle any brazing, sintering or heat treating operation.

The AT type Globar heating elements and the hearth rollers of alloy for 2100°F. maximum, or silicon carbide for 2500°F. maximum temperature, may be changed from outside without cooling the furnace down. Production delays are eliminated.

Both charge and discharge doors of the furnace open and close automatically. Gas flame curtains in front of and immediately below each door prevent oxidation and discoloration of work.

In the atmosphere-filled cooling chambers work is cooled at the most efficient rate since temperature level and flow of water in the water jacket are automatically controlled.

Let our engineering and research staffs find ways in which this furnace can handle your heavy work quicker, better and at lower cost.

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assembly moves to where the hydraulic mechanism is installed.

The center section of the tractor power plant is coupled to the axle assembly. The 4-cylinder motor is connected to the center section, appliances are installed, and levers, shields, radiators, rods, bolts and other fittings added. Then the entire assembly moves into the spray booth for painting, followed by baking with infra-red lamps. Surplus paint goes into a water bath and is removed to a reclamation center. Finally, oil, gasoline and water is added, and the tractor roars off the assembly line.

—P. D. Aird. *Mod. Industrial Press*, Vol. 7, Nov. 1945, pp. 36-38, 40.

The Improvement of the Deformability of Hot-Galvanized Layers

Condensed from "Stahl und Eisen"

Experiments in hot galvanizing are reported which were made with cold-rolled strips of steel (composition 0.09% carbon, 0.02% silicon, 0.45% manganese, 0.032% phosphorus, 0.036% sulphur, 0.05% chromium, 0.10% copper) 100 mm. long. They were dipped for 10 sec. into the zinc bath at 470 C (880 F).

A roughening of the surface proved to be advantageous, irrespective of whether it was done by emery (0000) or sandblasting, pickling in sulphuric, hydrochloric or nitric acid, and also rusting in the atmosphere improved the adhesion and thickness of the deposited layer.

When left to rust up to four or five weeks the resistance of the zinc layer against deformation was four to five times as great as in unrusted specimens. The optimum of thickness of zinc deposit in the case of acid pickling in all acids was at around 20% concentration.

On wires, thick zinc deposits with good deformability can be obtained by sandblasting. Electric heating of the wires permits elimination of pickling in acids and thus dragging along pickling residues; the zinc bath is here used as electrode.

An addition of 0.2 to 0.5% aluminum to the zinc bath avoids the formation of the hard zinc layer.

—W. Püngel & R. Stenkhoff. *Stahl u. Eisen*, Vol. 64, Nov. 9, 1944, pp. 720-725.

Tangent Bending

Condensed from "Steel"

Tangent bending is a cross between press forming and straight bending, in which the metal flows during the bending operation and its shape is controlled by a die. Benders have been developed which will form almost any metal product from thin strip through heavy plate, bars, tubes, and structural shapes.

Basic parts of the bender are the male die, the female die, which is mounted on a rocker plate, and the bending wing, which moves the rocker plate and applies the

power. In operation, the bending wing performs an arc around the male die, carrying with it the rocker plate and female die. The rocker plate is free to move across that portion of the piece being bent, which produces an "ironing" action. This slippage aids in the flow of metal and prevents tearing.

During operation the female die is constantly tangential to the male die, and the sliding pressure is applied in this same tangential direction. This provides a constant and even pressure on the work at all times during the operation.

Range of size of product is almost unlimited. The only differences would be in the size and design of the bender, and the amount of power required. There are several standard models in single-wing, double-wing, stretch-wing, and duplex benders, but a machine may be designed for a particular job.

Machines are operated by hydraulic power with electric controls. Operating speed ranges from 1200 complete cycles per hr. on the smaller and faster units down to as few cycles as required. The bending wings have a maximum swing of 109 degrees, which controls the maximum degree of bend obtainable in one stroke. Maximum radius obtainable is 6 in. on the double-wing machine. When making two bends simultaneously, the distance between centers of bends can vary from 17 to 31¾ in.

Relationships between dimensions have been developed for some of the more common bends. These make for the easiest processing of the metal. With use of notches radii may be made smaller and flanges wider, still leaving only flat surfaces for joining and no finishing required on the curved surfaces.

—*Steel,* Vol. 117, Sept. 17, 1945, pp. 124-128.

Electroplating on Aluminum

Condensed from
"Aluminium & The Non-Ferrous Review"

After reviewing and discussing the causes for the difficulties of electrodeposition on aluminum, the "Cromalin" process is claimed as the most successful process yet patented, as it is said to be corrosion-proof and suitable for decorative finish.

The adhesion of the plated-on metal is good; bending a full 360 deg. many times failed to raise or peel the deposited metal. Silver, nickel, chromium, tin, zinc, cadmium, copper, lead or gold give equally satisfactory results. It has been developed by A.E.R. (1938) Ltd.

The first object is to obtain a completely chemically clean surface on the aluminum by removing the oxide film. This is done so that as soon as the aluminum is cleared from oxide it is automatically sealed. Then it is treated by the company's special process, which ensures that the deposited metal has a perfect bond with the base metal.

—*Aluminium & Non-Ferrous Rev.,* Vol. 9, Oct.-Dec. 1944, pp. 52-55; Vol. 10, Jan.-Mar. 1945, p. 2.

METHODS AND PROCESSES

TESTING and INSPECTION

Testing methods and equipment for physical and mechanical properties, surface behavior and special characteristics. Radiographic, spectrographic, identification, metallographic, dimensional and surface inspection. Stress analysis and balancing. Specifications, standards and quality control.

Notch Sensitivity in Fatigue Tests

Condensed from a Paper of the American Society for Testing Materials

The effect of size of the specimen on endurance limit of steel specimens has been studied. The size effect in plain, unnotched specimens is computed on assumption that a fatigue specimen which fails under cycles of reversed flexure behaves as if a fatigue crack started slightly below the surface of the specimen, where the nominal stress is slightly lower than at the surface.

It is assumed that at this point below the surface the nominal stress at failure is independent of size of specimen and that the depth of this assumed starting point below the surface is also independent of the specimen size.

There was an appreciable difference among six steels between bright-annealed SAE 1035 steel polished before annealing and the same lightly machined and polished after annealing. The fatigue strength of the second was greater than that of the first and the notch sensitivity was less.

The tendency of test specimens with large cross sections to fail under repeated loading under lower computed stresses than those with smaller cross sections is a well-established fact. Testing machines were simple cantilever rotating beam machines.

The idea that the critical point where fracture starts is on the surface of a flexural test specimen, where the nominal tensile stress is greatest, is firmly fixed in our minds. The assumption that fracture may start very close to the surface seems reasonable. The polishing of the surface cold works and strengthens the "skin."

It seems reasonable that the actual fracture starts at the bottom of some inherent defect at the surface, or at some such defect slightly below the surface.

In tests on SAE 1035 bright annealed steel in diameters of 0.125, 0.250 and 0.500 in. it was found that both the unnotched specimens and the notched specimens of the annealed steel showed lower fatigue strength than the specimens tested in the as-rolled condition. Notch sensitivity of the annealed steel was distinctly higher than the as-rolled.

The strength-reduction factor for the annealed averaged 1.81, while for the as-rolled, 1.63. The bright annealing did not seem to affect the "size effect" but did increase the notch sensitivity. Machining and polishing lowered notch sensitivity to that of as-rolled, and the endurance limit of the annealed steel was increased 18%.

—H. F. Moore. Paper, *Am. Soc. Testing Materials*, Preprint No. 84, 1945. 15 pp.

Weldability Tests of Cast Steel

Condensed from "The Welding Journal"

The great increase in the use of welding in steel foundries has necessitated the development of methods for evaluating the weldability of cast steels. T-bend, nick-bend, underbead cracking, and a few tensile tests were made on steel castings with a wide range of chemical composition.

The T-bend and nick-bend tests are as satisfactory for cast steels as for wrought steels. They can be used to determine the effect of changes in welding technique and heat treatment on cast steels, and for the evaluation of the weldability of the various compositions of cast steel.

Although a 300 F preheat had little effect on the nick-bend ductility, an examination of the microstructure of the heat-affected zone of these weldments at 100 diameters showed the presence of a large

number of underbead cracks for some of the cast steels welded without a preheating. The 300 F preheat prevented this cracking. A stress relief treatment subsequent to welding in general greatly increased the ductility of the weldment.

Further work is needed to determine the effects of changes in composition and the variations to be expected for normal production heats in any steel foundry.

—F. S. McKenna & C. E. Jackson. *Welding J.*, Vol. 24, Nov. 1945, pp. 573-579.

Calculating Hardenability

Condensed from a Paper of the American Institute of Mining & Metallurgical Engineers

Adequate hardenability has long been recognized as one of the first requirements for producing desired mechanical properties in a heat-treated steel. The Jominy end-quench test and methods of calculating hardenability have made it possible to establish tentative hardenability bands for some of the more commonly used alloy steels, and have facilitated the design of new steels.

It was considered that it should be possible to predict the hardness in Rockwell C units by a more direct calculation. The addition principle is a reasonable approach to the problem.

The increments of Rockwell C hardness due to carbon and alloys are directly proportional to the amounts present, and are additive, so that their sum, including that for grain size and with the appropriate martensite increment, represents the hardness of the steel within an error of about ±6 points.

Of the different types of factor used, only the carbon-base hardness is dependent upon cooling rate, or position in the specimen, and even this relation is of secondary order. Alloy and grain-size increments are entirely independent of the other factors, while carbon-base hardness, martensite-base hardness, martensite factor, and maximum hardness are dependent upon carbon.

The amounts of alloying elements required for 1 Rockwell C addition unit are as follows: manganese, 0.065%; silicon, 0.200%; nickel, 0.182%; chromium, 0.067%; molybdenum, 0.027%. In the martensitic range, the effects of the alloying elements are in the same proportion, but smaller amounts raise the hardness by 1 Rockwell C unit, or, depending upon the carbon content, these amounts of alloys raise the hardness by from 1.25 to 4.0 Rockwell C units.

Steels with combinations of alloys, such as chromium and molybdenum, have been found to develop the full hardness estimated from the individual effects of their components.

The validity of the calculation of the hardness of Jominy test specimens has been confirmed by data from standard grades of steel, and the degree of accuracy indicates that the calculation may be useful in facilitating the prediction and control of hardenability.

—Walter Crafts & J. L. Lamont. Paper, *Am. Inst. Mining & Met. Engrs.*, Tech. Pub. No. 1926, Oct. 1945. 21 pp.

engineering BOOKS

Magnesium Fundamentals

INTRODUCTION TO MAGNESIUM AND ITS ALLOYS. *By John Alico. Published by Ziff-Davis Publishing Co., 350 Fifth Ave., New York, N. Y. 1945. Cloth, 6 by 9½ in., 183 pages. Price $5.00.*

By careful selection and proportioning of his material, the author has succeeded in covering the fundamentals of production and fabrication for those manufacturers and design engineers who may be considering magnesium alloy applications for their particular products and for research engineers, metallurgists and students who desire such aid in their work.

The book begins with a short history and the economic development of magnesium, following which five processes for obtaining the metal are described, one of which is sub-divided to include natural brines and sea water as sources.

Brief statements outlining investigations which have been made on 18 binary magnesium alloys are given for the benefit of research metallurgists who are interested in the development of new compositions. The commonly used methods and processes pertaining to the sand, permanent mold and die casting industries and to sheet, extrusion and forging manufacture are included for students and others who desire to familiarize themselves with such.

Those about to engage in the fabrication of magnesium products will find considerable help in the portion dealing with cutting, forming, drawing (including the recently developed rubber-forming method), machining, rivet and screw fastening, and torch, arc, and spot welding. Methods of surface treating and painting are included.

Numerous references are made throughout the text to the bibliography, which is placed at the end of each chapter. Approximately 125 published books and articles comprise the entire bibliography, which extends into 1945. Thirty-five tables, 25 plates, 11 diagrams and a comprehensive index make for clarity and ready reference.

The book does not contain the wealth of detailed technical data to be found in the English translation of Adolph Beck's "The Technology of Magnesium and Its Alloys." For this reason it is a much more readable book for those who are entering th magnesium industry, and for the reader primarily interested in a general picture of the magnesium industry, fabricating processes and uses.

—R. A. TOWNSEND

Atomic Energy

ATOMIC ENERGY IN WAR AND PEACE. *By G. G. Hawley & S. W. Leifson. Published by Reinhold Publishing Corp., New York, 1945. Cloth, 5¼ x 7¾ in., 211 pages. Price $2.50.*

Newspaper feature writers and pseudoscientific fictioneers have pounced upon atomic energy as the answer to all of our future problems regarding electrical power, heating, fuels for locomotion and many others.

Without attempting to discount the future uses of uranium or other sources of atomic power, this book discusses some of the practical considerations before us.

Much of this interesting and fast-paced book is devoted to a general discussion of atomic energy and the methods of releasing this energy from radioactive materials. However, the portion of greatest interest to readers of MATERIALS & METHODS is that section containing eight chapters on "Peacetime Future of Atomic Energy."

It is the general belief of the authors that it will be up to fifty years before there is any widespread use of atomic energy for the generation of electricity; as a replacement for gasoline in automobiles, or as the means of furnishing heat for home and factory. As a primary source of electrical energy, there remains inexpensive hydroelectric power; there is at present no means whereby a small enough unit of uranium can be utilized for driving an automobile; the use of radioactive materials to produce steam probably will require different materials—perhaps aluminum—for such products as boiler tubes. On the other hand, railway locomotives and ocean liners may use atomic energy in the not too distant future.

—T. C. DUMOND

Other New Books

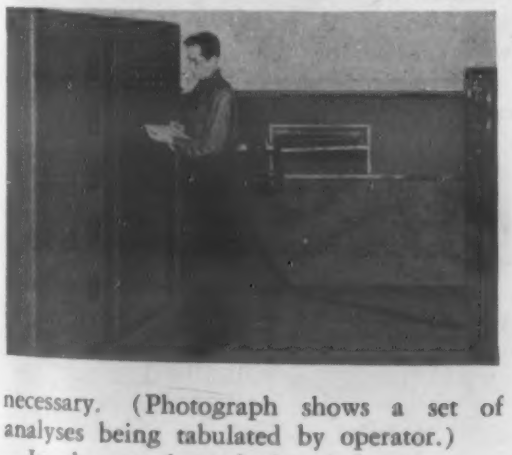
POLAROGRAPHIC AND SPECTROGRAPHIC ANALYSIS OF HIGH PURITY ZINC AND ZINC ALLOYS FOR DIE CASTING. *An Account of the Investigations Carried out by a British Standards Institution Panel of the Non-Ferrous Industry Committee 1941-1944. Published by His Majesty's Stationery Office, London, England, 1945. Cloth, 6 x 9⅝ in., 117 pages. Price 5s.* This volume contains four scientific papers which give a detailed account of the investigations carried out by the British Standards Institution Panels. This was commissioned by its parent committee to prepare recommended methods for the polarographic and spectrographic analysis of high purity zinc and zinc alloys for die casting. In order that an account of the experimental work leading up to the recommendations, which are to be published by the B.S.I., should be permanently available, and the intelligent adoption of the methods and their future development be encouraged, the Ministry of Supply has sponsored the publication of this book.

NEWS of the Metal-Working Industries

Quantitative Chemical Analysis Instrument

An entirely new direct-reading instrument which allows the quantitative chemical analysis of as many as 11 elements in metal alloys, chemicals, and many other materials in under 1 min. is announced by the *Applied Research Laboratories,* 4336 San Fernando Rd., Glendale, Calif. and the *Harry W. Dietert Co.,* 9330 Roselawn Ave., Detroit.

Quantitative spectro-chemical analysis is the specific purpose of this new instrument, the "Quantometer." Principal advantage is the great speed in simultaneously and automatically measuring the quantities of a number of elements present. Results appear directly as percentage composition on a series of counters, one for each element being determined. Only one operator is



necessary. (Photograph shows a set of analyses being tabulated by operator.)

In the metal producing industry, many separate melting operations or the holding of melts while composition is being checked can be eliminated. The Quantometer offers great savings in fuel and overhead. Alloys produced can be kept to much narrower specification-limits than has heretofore been possible.

The machine consists of three units, a source unit providing a powerful spark to the sample being analyzed, a spectrometer which disperses the light from the spark into a spectrum, and a recording console where the final analyses are shown.

The source unit differs from the conventional units used in spectrochemistry chiefly in the very high-intensity discharge which it produces. The spectrometer employs an original diffraction grating and is fitted with 12 receivers arranged to record light from as many spectrum lines. These receivers, employing highly accurate integrating electrical circuits, replace the troublesome photographic emulsion used in spectrography.

The recording console supplies all of the various voltage required to operate the receivers, and houses the counting units which provide the final direct analyses.

New Brazing Flux, Thin at 800 F

A new flux known as Nu-Braze Wonderflux No. 4 melts and forms a protective coating over the metal surfaces at 480 F, well below the oxidation temperature of most metals, thus eliminating oxides by actually preventing their formation. At 800 F, where ordinary brazing fluxes first begin to melt, Nu-Braze is actually water-thin, and will readily flow through clearances as close as 0.001 in. It is especially effective on stainless steels.

The new flux has a pH of 5 to 6, or completely neutral. Thus, it can be painted on parts and allowed to remain for long periods without producing corrosion. Since it is non-hygroscopic, should some of this flux remain trapped in an inaccessible part of the joint, it would not pick up water at a later date and thus cause corrosion.

Because it is water-thin at its operating temperature, this flux is gently and completely eased out of the joint by the molten brazing alloy, thereby eliminating flux inclusions in brazed joints. After it is melted, it hardens to an extremely brittle glass, which can usually be jarred from the brazed part. It is easily removed by either hot or cold water.

After the water content leaves the flux at 212 F, there is no further effervescence. This quality makes this flux especially useful where brazing alloys are used in the form of powder, since this flux will not spatter the alloy powder away from the joint area. It contains no free fluorides, and does not release the objectionable volumes of noxious fumes as do ordinary silver brazing fluxes.

This flux is manufactured by *Sherman & Co.,* 197 Canal St., New York 13.

● A new type phosphor bronze electrode, for use in all-position welding of brass, bronze, copper, cast iron and steel, has been developed by the *Alloy Rods Co.,* York, Pa. "Cupro-Arc C" can operate with direct current and reverse polarity. It has a smooth flowing arc that eliminates the erratic arc action of many bronze electrodes. Spatter loss is minimized.

Combined Ceramic and Plastic

A new material, which can be used to produce finished castings in 5 min., and which can be reclaimed like metals by melting, has been developed by *Duorite Plastic Industries,* Culver City, Calif.

It is a combined ceramic and thermoplastic called "Plastiform," and it has been used in making tools for aircraft work, art objects, protective coverings, insulators, scenic casts for stage and motion picture sets, toys, and office equipment.

Plastiform is prepared for casting by melting in a double boiler, whose outer container holds an oil bath to prevent overheating. It can be melted or remelted innumerable times without additives.

After it attains a temperature of more than 240 F, the material becomes a fluid which can be poured, brushed, sprayed, or dipped. Molds of almost any type can be used to give it a suitable form. In aircraft, Plastiform has been widely used in making dies for stretching metal parts. Such dies have withstood loads of as much as 1,250,000 lb., enough to shear the parts that were being stretched.

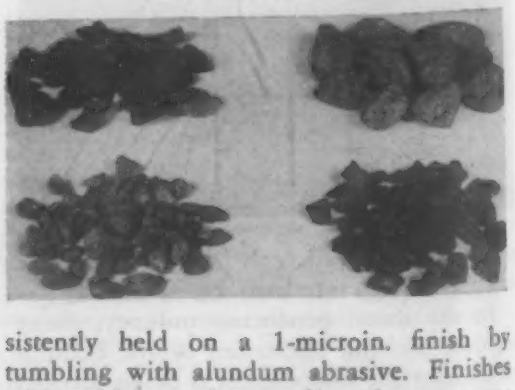
Alundum Abrasive for Wet Tumbling

Alundum abrasive is now being marketed by *Norton Co.,* Worcester, Mass., in a special form for wet tumbling. It is a hard, heavy, tough and fast cutting aluminum oxide product that is proving excellent for cleaning, deburring, finishing and the development of radii on a wide variety of metal parts.

Alundum abrasive is available in four size groups—¼ to ½ in., ½ to ¾ in., ¾ to 1 in., and 1 to 1½ in. diam., either untumbled or tumbled (sharp corners rounded). The accompanying illustration shows the smallest and largest sizes in tumbled form and the other two sizes untumbled. The extreme hardness provides continuous fast cutting action without glazing over.

Normally used with water and a cleaner, alundum abrasive for tumbling has proved to be superior to many methods of deburring and finishing. It has eliminated the variable results obtained by the usual manual bench operations. Radii on gears, for instance, have been held to exact blueprint specifications on lot after lot while costs were considerably reduced.

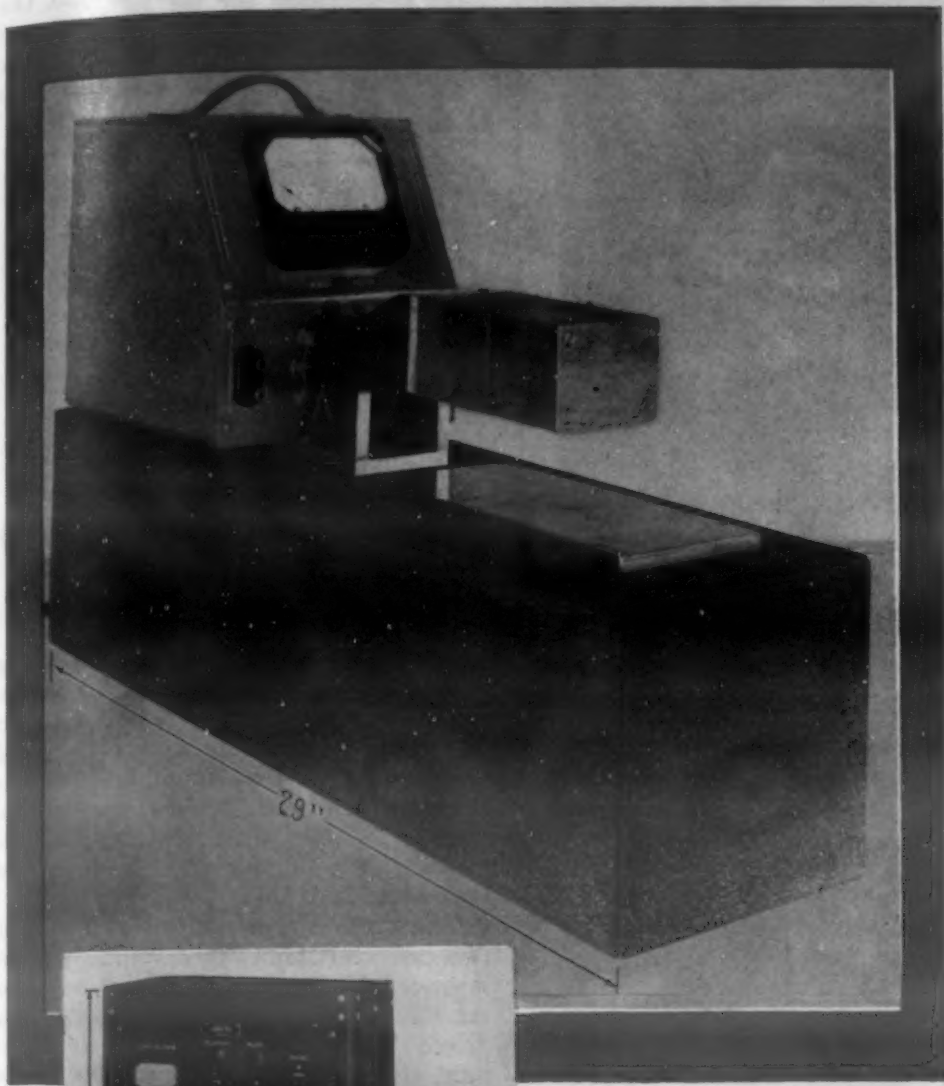
Microinch finish can be easily maintained or improved. Precision parts are being con-



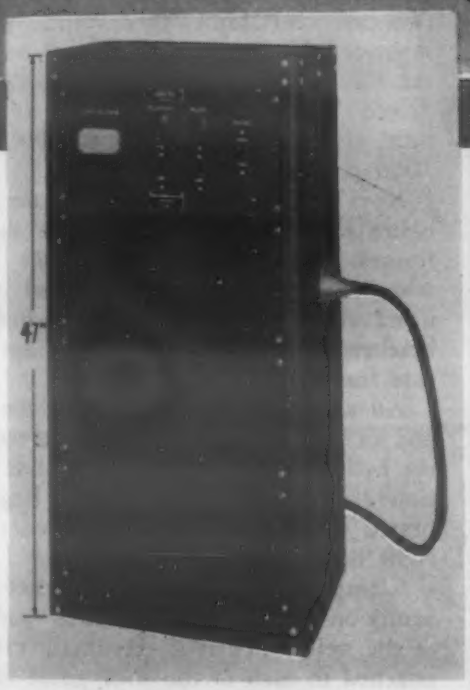
sistently held on a 1-microin. finish by tumbling with alundum abrasive. Finishes with a higher micro reading than one can be improved.

(*More News on page 558*)

Gaging Worries?



GAGE HEAD
AND METER



POWER SUPPLY

OUR X-RAY NON-CONTACT GAGE METER will give you a CONTINUOUS and ACCURATE reading of your output! It allows you to gage, measure or inspect your products with a speed and accuracy heretofore unattainable!

Even better, you can control output and keep it constant to an undreamed-of degree — thickness for example within 1% if this is what you need, or within 5% if that is enough.

Brass, copper, steel, aluminum, paper, cellophane, plastics, any sheet, any strip, any foil of any kind can now be gaged accurately and without contact.

And speed is no problem — 5 ft. or 5000 ft. per minute makes no difference.

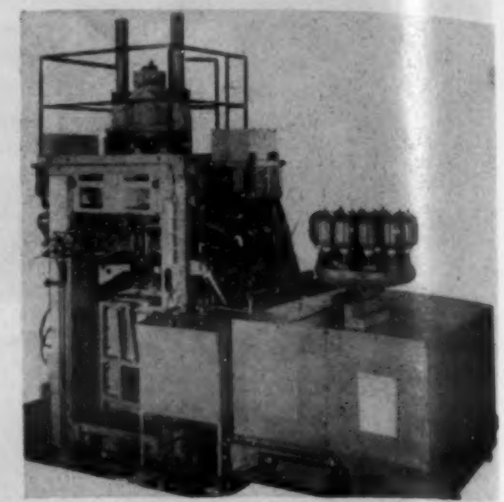
Be modern and eliminate rejects!

Check production and keep costs down!

X-RAY ELECTRONIC CORPORATION
Two East End Avenue
New York 21, N. Y.
REgent 4-4413

Large Vertical Flash Welders

Two of the largest vertical flash welders ever built, designed to join solid steel shafts to the turbine bucket wheels of jet propulsion engines, have been completed by the *Taylor-Winfield Corp.*, Warren, Ohio. One machine is for the General Electric Co. and the other for the Westinghouse Electric Corp. They are equipped to take shafts



from 1 to 6 in. diam., 12 to 72 in. long and bucket wheel diameters of 5 to 40 in.

Difficulty in keeping stresses in a straight line on the conventional type horizontal machines led to the designing of this machine in the vertical. Being of the hydraulic press type, close work alignment and allowance of minimum die deflection at the time of upset is made possible.

This machine is comprised mainly of two cast steel frames in a vertical position separated by cast steel brackets, bolted to the frames at each end. The upset slide is driven by a hydraulic cylinder of 35-in. bore giving a pressure of 850,000 lb. at 1000 p.s.i. line pressure.

Keys position both brackets, the upper being insulated electrically from the side frames. The platen, bearing the bucket wheel to be welded, is mounted on the upset slide, guided by two attached slide brackets moving vertically in bearings in the side frames.

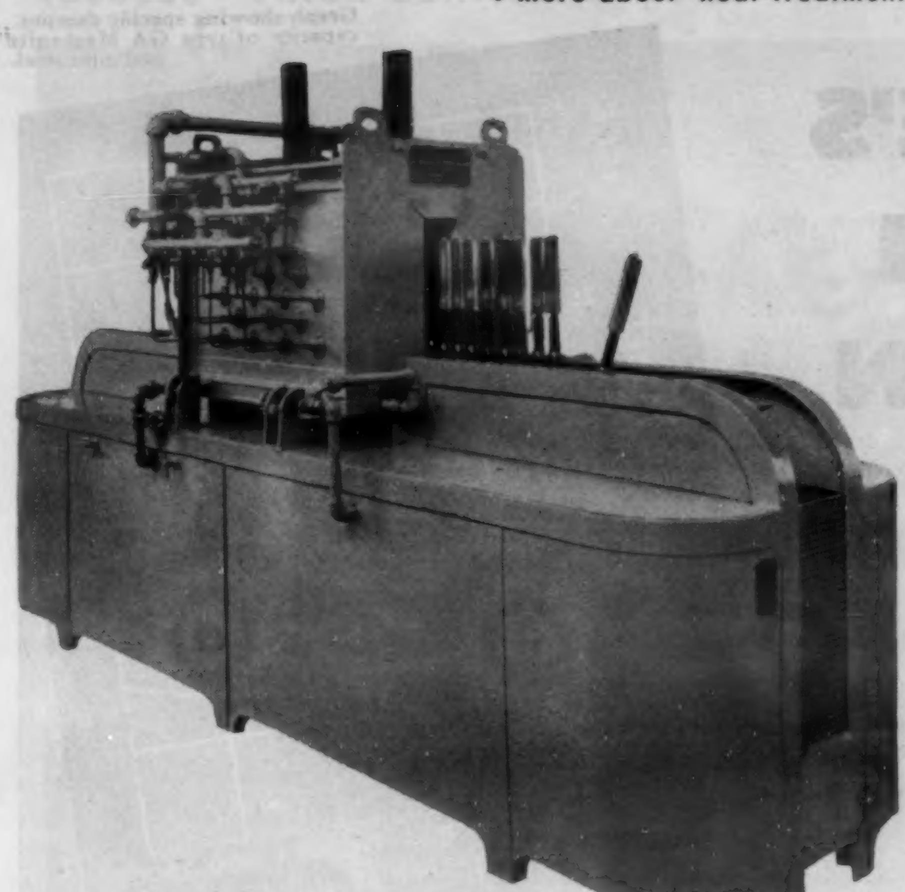
An adjustable bucking nut on the lower end of the piston rod limits the travel of the hydraulic piston. The upset slide's position and travel is shown by a large calibrated dial and pointer, mounted on the right hand side of the frame.

Clamping arms hold the bucket wheel firmly on the platen and serve as conductors of the welding current. Hydraulic cylinders attached to each of the slide guide brackets actuate the clamping arms.

The upset pressure is transmitted to the bucket wheel by the upset slide's integral back-up screw, adjustable to butt firmly against the bottom of the bucket wheel. A hydraulic toggle-operated horizontal clamping fixture on the lower face of the upper bracket clamps and supplies welding current to the shaft to be welded to the bucket wheel. Located at the control station are warning lights indicating whether clamps are in correct position.

The upper back-up screw, which butts against the upper end of the shaft, absorbs the upsetting force transmitted to the shaft being welded. Means are provided for proper alignment of the shaft and wheel.

(Continued on page 562)



Successful welding of turbine bucket wheel materials is largely due to the use of electronic heat control (by the phase shift) to adjust the welding current in five steps. The accompanying photograph presents a front view of the welder handling 3¼-in. shafts.

● Two new weld-spatter-resistant compounds, No. 9951 and No. 9952, have been announced by the Electric Welding Div., *General Electric Co.* Both are specially formulated for use wherever weld spatter is undesirable and must be avoided easily and economically. Furnished in powder form, ready to be mixed with water, the compounds are identical in performance. The only difference between them is that the No. 9951 is non-adherent and can be readily removed with an air hose or a dry cloth, while the No. 9952 is semi-adherent but can be quickly and easily removed with a damp cloth or a direct stream of water.

Dip Tanks for Corrosion Protection

A new line of dip tanks for preservation of material, tools and parts in ethyl cellulose and cellulose acetate butyrate is announced by *Aeroil Products Co.*, West New York, N. J. They are called "Plast-O-Dip", and protect against corrosion and abrasion in storage and shipping.

With the exception of the "one gallon Midget", these tanks operate on the double boiler principle with the heating elements in the oil bath (lower boiler). The model illustrated is a 2½-gal. dipping tank.

The manufacturer guarantees no hot spots or scorching with an accurately controlled temperature up to approximately 600 F. The tanks are heavily insulated and

are safe and easy to handle. They operate either with 110-v. or 220-v. current. No mother tank is required.

A special dividing partition makes it possible for new melt (blocks) to be added on one side of the tank without disturbing the temperature control or dipping applications in the main part of the tank.

(More News on page 566)

Vapor Degreaser

A vapor degreaser that operates in a ferris wheel manner and called the "Rotomatic" is announced by *Phillips Mfg. Co.*, 3435 Touhy Ave., Chicago 45. It incorporates both semi-automatic operation and a controlled cleaning cycle. The loading device consists of a rotating frame from which baskets are suspended.

It is motor-driven and governed by an automatic limit switch and interval timer which brings each basket to the opening for loading and unloading and automatically swings it into the vapor bath for the correct cleaning time. The machine eliminates costly drag-out of solvent vapor and minimizes spreading of fumes and odors.

The unit is completely hooded with hanging door covering the opening for loading and unloading baskets, and is available in three sizes, handling approximately 1200, or 3000 or 4000 lb. per hr.

● A sturdy hardwood veneer, faced with resin-bonded cylinder kraft, called "Tekwood," is announced by *U. S. Plywood Corp.*, 55 W. 44th St., New York 18. It is tough, yet bends readily, if desired. It die-cuts easily with perfect, clean edges. It is used for furniture and cabinet backs, displays, games, cut-outs, luggage, etc.

Model Machine Shop for Veterans

A model machine shop suitable for one-man operation, such as a returned veteran, and which can be housed in the back of a store, 2-car garage, or basement, is being sponsored by the *DoAll Co.*, 264 N. Laurel Ave., Des Plaines, Ill.

The equipment of one of the eight model service and repair shops includes a contour sawing machine, supply cabinet, drill press, tool cabinet, lathe, arbor press, bench drill press, toolmaker's bench, vise, bench plate, tool grinder, anvil, electric arc welder, oxyacetylene welder, rough bench, vise and stock storage rack.

A 64-page booklet, "Make Money with Your Own Shop," has been prepared by the DoAll Co., Minneapolis.

(More News on page 570)

New Alloy Electrical Contacts

A new series of electrical contacts made from silver tungsten and silver tungsten carbide is sponsored by *Gibson Electric Co.*, 8356 Frankstown Avenue, Pittsburgh 21.

They have higher current carrying capacity, greater non-welding characteristics, and longer life, hence one can utilize higher current densities, with resultant increased efficiency in performance, and lower cost types of construction. On an air circuit breaker, a contact with less than 1/6 sq. in. of contact area could repeatedly break 15,000 amp. circuits at 600 v., without sticking, welding, or excessive wear.

Made by a special process from metal powders, these electrical contacts comprise a range of combinations in the silver tungsten series from 10% to 80% tungsten, and in the silver tungsten carbide series from 20% to 80% tungsten carbide, with hardnesses from Rockwell 80 to 100 B.

● A precision magnifying scale, called the "Micro Scale," is for use of aircraft workers, shipbuilders, tool makers, engineers, draftsmen, etc. A magnifying glass enlarges the critical portion of the scale. It is distributed by the *Leonard Engineering Co.*, Silver Spring, Md.

Baking Enamel

A high-grade baking enamel, unusually fast drying and almost indestructible, has been developed by the *H. V. Walker Co.*, Elizabeth, N. J. Called "Porciflex," this new paint, when applied to metal, gives a flexible porcelain-like finish with high resistance to acids, alkalis, oils and greases.

Applied by spray, roller-coating machine, or dip, Porciflex is baked at schedules from 1 min. at 450 F for sheet metal to 15 min. at 275 F for other types of work. It is adapted to infra-red baking. It is available in clear, black, white and all colors. The white has a minimum tendency to yellow

with age. It will not crack or flake when struck, and will not peel off under normal conditions.

In the accompanying photograph the enamel is being sprayed on fluorescent lighting fixtures.

(More News on page 574)

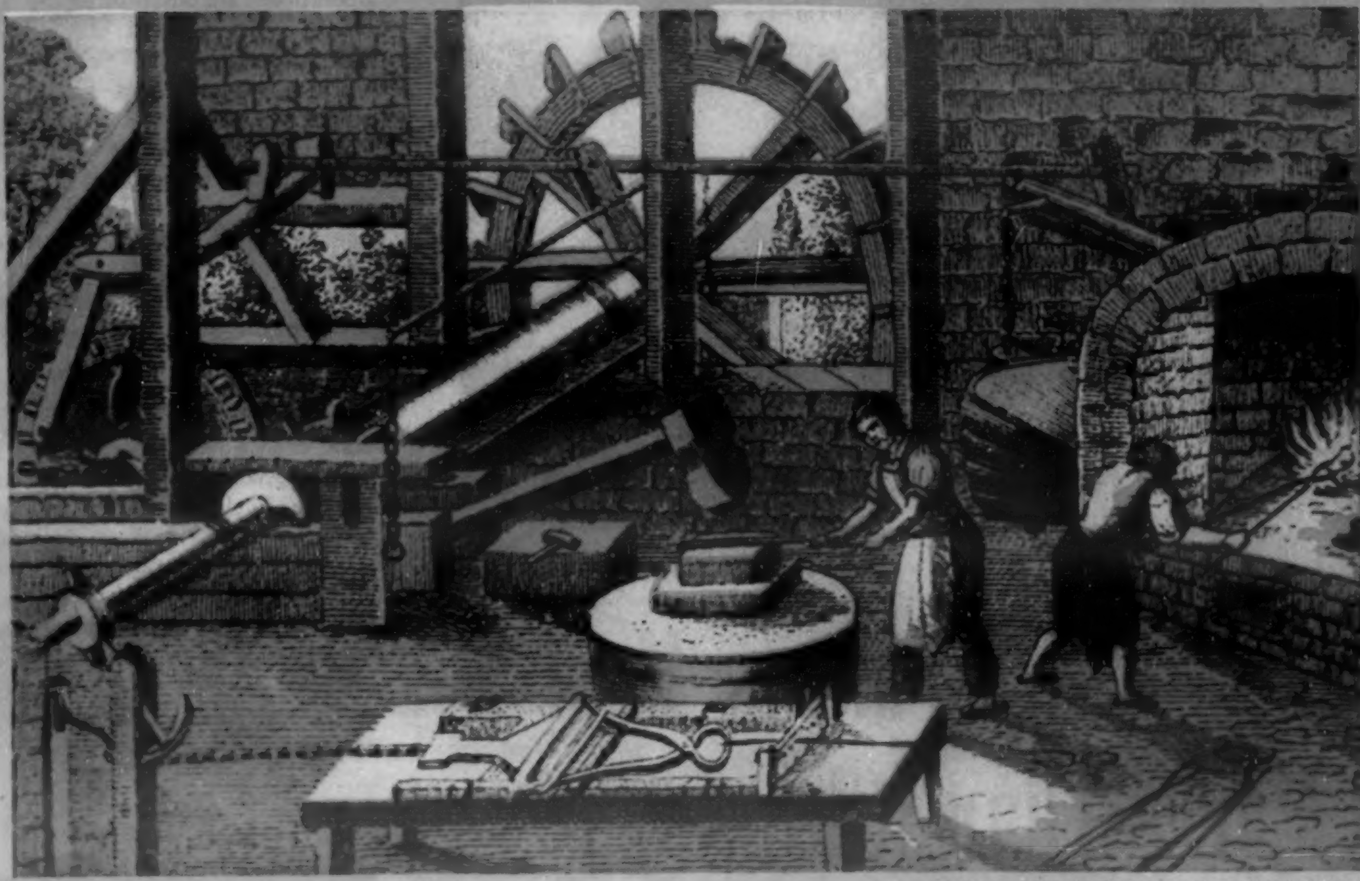


PHOTO COURTESY OF THE BETTMAN ARCHIVE

FROM A METAL-MASTER'S "FAMILY ALBUM"

WHEN FORGE SHOPS LOOKED LIKE THIS

STANDARD STEEL'S present home was a metal production center

This highly mechanized forge shop represented advanced practice in the early 1800's. Power from the giant undershot wheel not only operated the heavy trip hammer, but also pumped the bellows, and provided pull for the ingenious primitive draw-bench in the foreground. Yet when this equipment was a marvel of progress, Standard Steel's ancestor, "Freedom Forge" was already a going concern. As early as 1811 a blast furnace was erected, which was replaced in 1820 with another having a stack 20-feet high and a bosh 7 feet in diameter. Output was from 12 to 15 tons of blooms and bar iron a week.

Standard Steel's present forge shop would amaze the metal workers of yesterday. Fourteen steam hammers with capacities of from 3500 to 12,000 pounds and six presses with from 600 to 2500 tons capacity produce 15,000 tons of locomotive forging and 30,000 tons of miscellaneous forgings annually. Any pressed or hammered forging up to 25 tons weight can be handled.

Whenever you need forgings or castings, remember that 151 years of accumulated experience plus complete modern facilities are waiting to serve you here. To simplify your problems, "Standardize on Standard."

BLW THE BALDWIN GROUP

BALDWIN

FORGINGS AND CASTINGS

The Baldwin Locomotive Works, Standard Steel Works Division, Burnham, Pa., U.S.A. Offices: Philadelphia, New York, Chicago, St. Louis, Washington, Boston, San Francisco, Cleveland, Detroit, Pittsburgh, Houston, Birmingham.

"STANDARDIZE ON STANDARD" FOR YOUR FORGINGS AND CASTINGS

Coolant Filters and Sump Cleaners

Four new products designed to improve machine tool production, prolong tool life, cut down rejects and simplify sump cleaning operations are announced by *Honan-Crane Corp.*, 590 Wabash Ave., Lebanon, Ind. These are called the "Centri-Power" coolant filter, mobile coolant filter, sump cleaner and oil transfer truck and sump cleaner.

The coolant filter is automatic except for the manual changing of filter pads, which rarely have to be changed more often than once in 24 hr. on heavy cuts and once in three days on finish grinding or honing. The mobile coolant filter operates on a vacuum and the motor automatically stops when the tank is filled.

The sump cleaner is a mobile self-contained, well designed unit, consisting of tank, motor-driven pump, long suction hose with special nozzle and large roller bearing wheels. It cleans a sump in the fraction of the time of hand cleaning, and eliminates all slop and mess on floors.

The oil transfer truck and sump cleaner functions much as the mobile sump cleaner, but can also be used as an oil dispenser. Its primary purpose is to remove oil, dirt, chips, scale, etc. from machine tool sumps or tanks.

Plants and Slants

A silver plaque of the Great Seal of the State of Missouri was presented recently to the battleship *Missouri* on behalf of the mine, mill and smelter works of the *St. Joseph Lead Co.* The 30-lb. plaque was cast from silver mined in St. Joe's Missouri lead mines. Over 10,000 witnessed the presentation ceremonies at Flat River, Mo., including many "high-ups" from the Navy and civilian governments. President Truman and Navy Secretary Forrestal sent messages.

Useful work for seriously disabled war veterans is being provided at *"Valor,"* a unique plant at the Percy Jones General Hospital Annex, Fort Custer, Mich. The men, all with severe spinal injuries, learn to become industrial inspectors in a short time. A typical job is checking the precise measurements of airplane engine valves with Federal dial indicating gages for *Eaton Mfg. Co.* They work two hours each forenoon and two each afternoon. The plant is complete with gages, indicators, comparators and fluorescent lighting. As one official expresses it, "Just to see the fellows brighten up, to be cheerful and busy again is worth every effort that has been expended."

A silver plaque honoring John Cromwell Lincoln as founder of the *Lincoln Electric Co.* was presented recently by the firm's employees at Cleveland as a token of their esteem to mark the company's 50th anniversary. Lincoln started the concern with a capital of $150, a firm which grew into the largest producer of electric arc welding equipment.

(Continued on page 578)

After three years of research *Butler Bros.*, St. Paul, Minn., are now operating a large scale electrolytic iron powder pilot plant at their mining site in Cooley, Minn. A commercial plant will be completed in late 1946 to make "tailor-made" powder blends.

A new series of research positions designed to make science as a career as attractive as the administrative field in industry has been announced by the Technical Div., Rayon Dept., *E. I. du Pont de Nemours & Co., Inc.* New opportunities will be offered as to salary, responsibility and prerogatives. The new classifications are open to chemists, engineers and other technicians.

The Reynolds Metals Co. has leased from TVA for 10 yr. with a purchase option Nitrate Plant No. 1, Sheffield, Ala. It will be used for production of building products, will employ 400 to start, and consists of 10 buildings, an office building and 65 acres.

Carnegie-Illinois Steel Corp. will increase facilities for cold reduced sheet and tinplate at Gary, Ind. by 232,600 tons annually to over 1,250,000 tons. The Gary mill is already the largest of its kind in the world.

At the new plant on Eight Mile Road, Detroit, which *Carboloy Co., Inc.* is building, there will be a new type of dust collecting system superior to others. Furnaces in which powdered metals are converted into cemented carbides will have suction hoods to lessen heat. "Air locked" doors will keep out wintry blasts. A high ceiling will help reduce noise. "Ball" mills for mixing metal powders will be mounted on vibration absorbing material. Conveyors will be used widely.

Peace-time facilities of *Pemco Corp.*, Baltimore, have expanded, thanks to foresight during war time. Instead of building temporary auxiliary structures, the company built permanent ones which have now been moved into for peace production, giving the company the largest and most complete group of laboratories in the porcelain enamel industry.

Tube Turns, Inc. will lease from the Reconstruction Finance Corp. the $3,000,000 worth of D.P.C. equipment installed for war work, and will purchase $500,000 of additional equipment.

Stephen A. Brooks and seven associates, each with extensive experience in rotameter manufacture and application, have organized the *Brooks Rotameter Co.*, with factory at Lansdale, Pa. The company will specialize in rotameter flow rate measuring instruments.

The B. F. Goodrich Co., which 50 yr. ago established the first research laboratory in the rubber industry, has broken ground for a complete research center on a 260-acre tract halfway between Akron and Cleveland. There will be five buildings. Removable partitions, interchangeable fixtures, etc. will make them flexible. The site was chosen because of its freedom from dust, cross-country electric lines, vibration and noise.

George W. Walker, industrial designer, New Center Bldg., Detroit, has opened branch offices in London where he will help

(*Continued on page 582*)

adapt American design to mass production by British industry. Mr. Walker has designed automobile bodies and interior appointments and household appliances.

Wabash Appliance Corp. has merged with *Wabash Photolamp Corp.* and *Birdseye Electric Corp.* to become a subsidiary of *Sylvania Electric Products, Inc.* Among products of Wabash are infra-red lamps.

Hydro-Power, Inc., designer and builder of hydraulic pumps, valves and controls, will build a new factory at Springfield, Ohio.

The operation of *Plastoweld Co.* and *Industrial Rubber Process Co.*, J. I. Spanich Welding Co. subsidiaries, has been consolidated. Both do cycle welding, and are producers of stampings and weldments.

The *Westinghouse Electric Corp.* has acquired the Curtiss-Wright plant at Buffalo and will move to that plant from East Pittsburgh the manufacture and insulation of copper wire, arc and resistance welding facilities, manufacture of electrodes and copper and selenium rectifiers. About 6,000 workers will be added to the Buffalo area.

The *Federal Machine & Welder Co.*, Warren, Ohio, has bought the Sommer & Adams Co., Cleveland designer and builder of special machine tools for automotive and aviation industries, and has also entered the metal furniture manufacturing field by establishing a new division, called "Modera."

The Stewart Industrial Furnace Div., *Chicago Flexible Shaft Co.*, recently moved to a new building with 104,000 sq. ft. at 4433 Ogden Ave., Chicago.

W. C. Dillon & Co., Inc., Chicago, is an unusual organization in that a father and six sons hold prominent positions, the father being president.

News of Engineers

Raymond Vines, formerly with Ford Instrument Co., is now metallurgist with the Dentists Supply Co., York, Pa.

George D. Cremer has returned to the Hardy Metallurgical Co., New York, after two years with the atomic bomb plant at Los Alamos, N. M. He will supervise the Hardy powder metallurgy research and development laboratory.

Three Westinghouse men in the welding department of the motor division have been promoted. *Charles H. Jennings*, internationally-known arc welding expert and director of all welding research for the past nine years, becomes engineering manager of the welding department. *John H. Blankenbuehler* becomes manager of arc welding apparatus, while *E. Hill Turnock, Jr.* is now manager of arc welding electrodes.

Bingham H. Van Dyke has been made manager of the new products department of the Elliott Co., Jeannette, Pa., maker of gas turbines. He was previously assistant to the director of research and development, and before that was with WPB as deputy chief of the heat exchanger and pressure vessel branch.

(Continued on page 586)

Dr. Charles S. Keevil, who was connected with flame warfare research and development at Edgewood Arsenal, has joined Arthur D. Little, Inc., Cambridge, Mass., which has been engaged by the Artillery Div., Ordnance Dept., to experiment with long-term storage of ordnance equipment. *Alf K. Berle*, formerly concerned with the supply of scientific equipment for the Office of Scientific Research & Development, will serve as special consultant.

W. S. Mounce, formerly senior metallurgist, Hamilton Standard Propellers Div., United Aircraft Corp., has joined the development and research division, International Nickel Co., Inc., making his headquarters at Hartford. *Dr. John G. Dean* has also joined that department at New York, having been senior fellow-in-absentia of Mellon Institute of Industrial Research, Pittsburgh.

Ashton G. Work has been appointed Philadelphia distributor for the Claud S. Gordon Co., engineering, equipment and service.

Rolland R. LaPelle, formerly manager, special furnace division, Dempsey Industrial Furnace Corp., Springfield, Mass., has been elected vice president.

Thomas B. Blackwood has joined the metallurgical department, Vanadium-Alloys Steel Co., Latrobe, Pa., having formerly been with Universal Cyclops Steel Corp.

Walter F. Nessen has been appointed chief industrial designer for Product Designers, Chicago, his experience having embraced the automotive, railroad, household appliances, drafting and blueprint machinery, power tools and radio fields.

Dr. Richard J. Lund has joined Battelle Memorial Institute, Columbus, to make studies of technical-economic problems. Until recently he was with the Reynolds Metals Co. as director of basic research. He is author of many technical articles, was former editor of *Mining Congress Journal*, and belongs to several technical societies.

Dr. Stewart G. Fletcher has joined Latrobe Electric Steel Co. as chief research metallurgist, to probe all phases of high-speed steel, tool steel and die steel production. He was educated at both Carnegie and Massachusetts "Tech." He was awarded the ASM Howe medal in 1945 for the best technical paper of the year.

C. L. Hancock has been promoted to manager, technical service department, Bridgeport Brass Co., having been with the company for 25 years.

Col. M. E. Erdofy, consulting metallurgical and industrial engineer, has joined the executive staff of Lithaloys Corp. During the past four years he was with the Corps of Engineers, U. S. Army.

T. E. Eagan, chief metallurgist, Cooper-Bessemer Corp., has been appointed chairman, Gray Iron Div., American Foundrymen's Assn.

Cleo E. Gustafson has been made superintendent of the Gary, Ind. plant, Union Drawn Steel Div., Republic Steel Corp. He has had 28 years experience in the manufacture of cold drawn steel.

(Continued on page 590)

Robert M. Zeller, formerly with the Carpenter Steel Co., Reading, Pa., is now with the Aetna-Standard Engineering Co., Youngstown, Ohio. He is a roll designer, and his capacity in the roll sales division will be that of roll engineer.

House Organ Notes

Nickelsworth, International Nickel Co., Inc., Vol. 12, No. 3.

A short while ago, a Coast Guard-manned transport was plowing through a heavy sea on its way from Australia to India. While securing loose gear in the bow, BM 1/c Alex Kanderson was picked up by a huge wave and smashed against a bulkhead. Both bones above his left ankle had been splintered. The sick bay lacked a metal plate needed to hold the bones together after they were set. Things looked hopeless . . . but not for long . . . for three engineering officers obtained a spare Monel motor shaft, and worked uninterruptedly for the next 12 hr. to get the plate down to the proper dimensions while a heavy sea pounded the ship. When finally finished, the plate measured 4½ in. long, ½ in. wide and 3/32 in. thick. Screws needed for the plate were made from Monel rods which were taken from one of the ship's coffee urns. When plate and screws were ready, the ship's surgeon operated, bound the bones tightly, and sent the sailor off to bed.

Steelways, American Iron & Steel Institute, No. 2.

Europe in the 16th century had been devastated by war. Epidemics, famine and depression had followed. Then one day, so legend goes, a troubadour walked through the streets of Vienna, playing a lute and singing "Ach du lieber Augustine." Those who heard him remembered the cheery, lilting tune. Soon all Europe was singing it. People again began to work and hope. Ever since he first plucked a taut string and found its tone pleasing, music has given man hope, courage, glimpses of beauty. Spanning 25 centuries, gut, silk strings and later steel wires have paced the march of music down to our time and to our basic instrument — the piano. Modern pianos make music from steel in the form of strong, tough highest quality wire. A piano with 88 notes contains about 226 individual wires. Steel's physical properties and piano wire's precise shape make it possible for one man to produce from a piano the volume, depth and richness of tone to match a symphony orchestra. The wires in a modern piano are under a combined pull of 17 tons—almost five times the tension of the strings in an old square piano and countless times the tension in a spinet.

Westinghouse Newsfront, Westinghouse Electric Corp., January, 1946.

It's hard to imagine birds being cooked while still in flight. But that's actually what happened during the war when several low-flying fowl accidentally swooped into the mouth of a giant radar antenna used to jam enemy search equipment. The powerful beam of high-frequency waves stunned and roasted the birds almost instantly. Although the day of high-frequency cooking is still in

the future, the incident points up another important job already being done by versatile short waves. The same energy that is used to carry the human voice or detect distant unseen targets can be applied to drying food, curing rubber, bonding plastics, flowing tin, and to scores of other industrial tasks.

Aluminum News-Letter, Aluminum Co. of America, December, 1945.

A gathering place where real sporting blood flows through the veins of the contestants is the Chicago Model Race Car Assn., which races miniature autos on a 20-lap, one mile stretch. Many of the cars are built by tool makers and other mechanics. The cars have about 12½-in. wheel base and 7½-in. tread, driven by small gasoline engines of 10 c.c. piston displacement with the crankshaft mounted in ball bearings. The engine is mainly of aluminum castings, using a Meehanite cylinder liner shrunk into an aluminum housing. Frames and rear axles are of cast aluminum or magnesium, with all parts machined to very close tolerances. Rules are that the cars weigh a minimum of 1 lb. for each 1/10 cu. in. piston displacement. Sheet aluminum goes into the bodies. The record to date is 80.09 m.p.h. Watch out there, brother, the flag has been dropped and here come four cocky little whoosis down the track!

Tin and Its Uses, Tin Research Institute, September, 1945.

Canned food, 93 years old, was found by an expedition in 1944 through the North-West passage from Halifax to Vancouver by the "St. Rock," schooner of the Royal Canadian mounted police. These 1944 explorers came across a cache of provisions left on Dealey Island in latitude 75 deg. N. by Capt. H. Kellett of "H.M.S. Resolute" in 1852. Many of the cans of food were still intact despite repeated freezings and thawings and rusting in the moist air. Some cans contained stewed ox-cheek, still wholesome as proved on laboratory animals. No bacteria had lived in the sound cans and no preservatives, such as borates or nitrates, had been used. Inside surfaces were still bright and in good condition. However, a can labled "carrots" was so badly corroded that appearance and flavor were not recognizable. The labels proclaimed Henry Gamble, Leadenhall St., London and 2 Royal Exchange, London. Gamble was the first to pack foodstuffs in tinplate in 1811.

Vernon Alcoan, Vernon Works, Aluminum Co. of America, November, 1945.

Notice the difference in cigarettes and chewing gum lately? That's because these are once again wrapped in aluminum foil. Chocolate bars, other confections, some types of cheese, yeast cakes, dried fruits and other grocery items are also beginning to reappear in aluminum foil packaging. All are fresher, more flavorful and better textured. Aluminum foil holds in the original flavor and moisture, prevents foods from becoming stale, soggy, or even rancid, by keeping the light and air from attacking their quality. Soon many other grocery items will have the protection of this wrapping, and housewives will be able to buy it in convenient roll form for use in their own kitchens.

Bellringer, Bell Aircraft Corp., November-December, 1945.

A layout in miniature of the entire Niagara Falls factory area has been painstakingly constructed and assembled by the plant layout department to facilitate moves or other changes in the layout of machinery, departments or whole areas. Three-dimensional scale models are used extensively in the layout, which incorporates every piece of equipment on the factory floor as well as much of the mezzanine surface. Use of the "board" in planning and executing moves of equipment or departments has practically eliminated the tedious and lengthy preparation of draftsmen's drawings, has influenced the expedient rendering of more permanent and effective decisions, and has resulted in a considerable savings of time and money. The models reproduce the factory on the scale that 1/4 in. equals 1 ft., and the models, particularly those of huge and complicated pieces of machinery, are marvelously detailed replicas in miniature. An inexpensive plastic molding process produced most of the models while others were made on a semi-production basis. The layout board includes everything from a 6-in. grinder to a 5000-ton press, plus realistic wire cribbing, office partitions as well as the different stages of product assembly and the assembly line.

Sperryscope, Sperry Corp., December, 1945.

"The defeat of Japan was full and complete and no one knew this better than the Emperor," states Paul Manning, writer, who was at the scene on both V-E and V-J day. "Up to the hour when Hirohito agreed to the Potsdam terms of surrender, the Japanese people believed victory would come to Japan. They firmly believed that only remnants of America's navy were shelling the coastal cities; they knew that American bombers were causing widespread destruction, but all this was outweighed by the official rumor that 3,000,000 bombers were hidden in the mountains of Japan. Only the inner cabinet knew this to be a lie. It was a cataclysmic shock to the people when the Emperor announced surrender; a shock which took several weeks to wear off. The signing of Unconditional Surrender on board the USS 'Missouri' in Tokyo Bay was impressive because of perfect staging. It was far different from Unconditional Surrender at Rheims, France, which I witnessed and broadcast last May. At Rheims, German surrender had been sudden and abrupt, and although it was the event the world had been waiting for, it nevertheless came with a swiftness that was climactic. There was no opportunity, or desire, to stage this surrender on the grand scale which later stamped Japanese surrender in Tokyo Bay."

Briefs on Associations, Promotions and Education

A "bridge of metals reaching toward new horizons in technology" was forecast by Cyril S. Smith, professor of metallurgy, and director of the newly established Institute of

(Continued on page 598)


Upton BUILDS SALT BATH FURNACES
to Unbelievable Sizes
Salt Bath Furnaces have certain definite advantages that can not be duplicated with any other type of heat treating methods.
Upton Electric Salt Bath Furnaces, using the exclusive Sealed Electrode principle of heating the salt right at the bottom of the pot, are being built in unbelievable sizes.
Sealed Electrodes—guaranteed for the life of the furnace—need no changing, require no "down" time for changing.
UPTON
This Upton Furnace for treating Stainless Steel Sheet is the first Electric Salt Bath Furnace of its size built anywhere. It is now in full operation and, like its size, is producing work of unprecedented excellence.
UPTON
Sealed Electrodes in the Upton Furnace permit building a furnace for your work; as deep and as long as needed to accommodate the work and as narrow as permissible to cut radiation losses to a minimum.
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Metals at the University of Chicago. "Metallurgists kept ahead of the engineer in properties of metal and methods of quantity production in the 19th century, but they are lagging in the 20th. Metallurgists have studied the alloys of the industrially important metals and have aimed to promote the profitable use of these rather than to gain basic understanding. A particular feature of the Institute will be the low temperature laboratory for studies of metals, etc. at temperatures down to those of liquid helium and below."

Fundamental knowledge of the "why" of the heat-resistant alloys which made possible the gas turbine and jet- and rocket-propelled planes is being sought in a program of research begun at Battelle Memorial Institute under sponsorship of the Navy's Office of Research and Inventions. They will try to put knowledge of high temperature materials on a scientific basis.

Frank E. Wartgow, formerly with Hasbrouck Haynes Engineers and American Steel Foundries, has joined the National headquarters staff at Chicago of the American Foundrymen's Assn. to head up plans for its 50th anniversary in 1946, culminating in a foundry congress and show in Cleveland May 6-10. Herbert F. Scobie, chemist and educator, is now with A.F.A. in its training and educational activities, particularly as they affect young men.

The date of the National Chemical Exposition has been moved up to Sept. 10-14 and will be held in the Chicago Coliseum. A registration of over 21,000 is expected.

The American Society of Mechanical Engineers has sponsored the formation of a machine design group, organized primarily for the presentation of technical papers of interest to machine designers generally. The secretary is B. P. Graves, director of design, Brown & Sharpe Mfg. Co.

At the recent second annual meeting of the Cutting Tool Manufacturers Assn., it was revealed that a study of wage rates in Detroit industry indicated that the rise in wages in cutting tool plants during the war had been much in excess of that for other industries. The new association president is E. A. Goddard, general manager, Goddard & Goddard Co., Detroit.

The Acid Open Hearth Research Assn., P. O. Box 1873, Pittsburgh, has brought out its first research bulletin, "Acid Open Hearth Slag Fluidity and Its Significance."

The first chapter of the American Foundrymen's Assn. below the Rio Grande River is its 32nd chapter, recently formed at Mexico City, Mexico following a petition signed by 56 prominent foundrymen in that district.

T. J. Ess has succeeded Brent Wiley as managing director of the Association of Iron & Steel Engineers, Empire Bldg., Pittsburgh 22. Mr. Ess has had 15 years of steel plant experience. Mr. Wiley will continue with the association as advisory consultant over a period of five years.

To stimulate undergraduate interest in welding, funds have been donated by A. F. Davis, Lincoln Electric Co., for a welding award, consisting of four cash prizes totaling $700 for authors and publications involving the best articles on welding pub-

lished in undergraduate magazines or papers during the preceding year. The announcement is made by the American Welding Society.

A program of research on the patented malleable iron, Z-metal, has begun at Battelle Memorial Institute. Work will be done on melting, alloying, casting and heat treatment. The research will be done in cooperation with the Z-Metals Research Institute, Inc.

The Chicago Technical Societies Council, representing 46 scientific, engineering and technological societies with a combined membership of over 17,000, will hold a "production show" March 20-22 at the Hotel Stevens, involving production tools, materials, handling devices, control instruments and factory equipment. The executive secretary is Paul A. Jenkins, 53 W. Jackson Blvd., Chicago 4.

The Engineering Experiment Station, University of Illinois, Urbana, has issued a paper by Harold L. Walker on "Grain Sizes Produced by Recrystallization and Coalescence in Cold-Rolled Cartridge Brass."

Meetings and Expositions

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, Iron & Steel and Institute of Metals Divs., national meeting. Chicago, Ill. February 25-28, 1946.

AMERICAN SOCIETY FOR TESTING MATERIALS, Committee Week. Pittsburgh, Pa. February 25-March 1, 1946.

EXPOSITION OF CHEMICAL INDUSTRIES. New York, N. Y. February 25-March 2, 1946.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, spring meeting. Chattanooga, Tenn. April 1-4, 1946.

SOCIETY OF AUTOMOTIVE ENGINEERS, spring meeting. New York, N. Y. April 3-5, 1946.

AMERICAN CHEMICAL SOCIETY, spring meeting. Atlantic City, N. J. April 8-12, 1946.

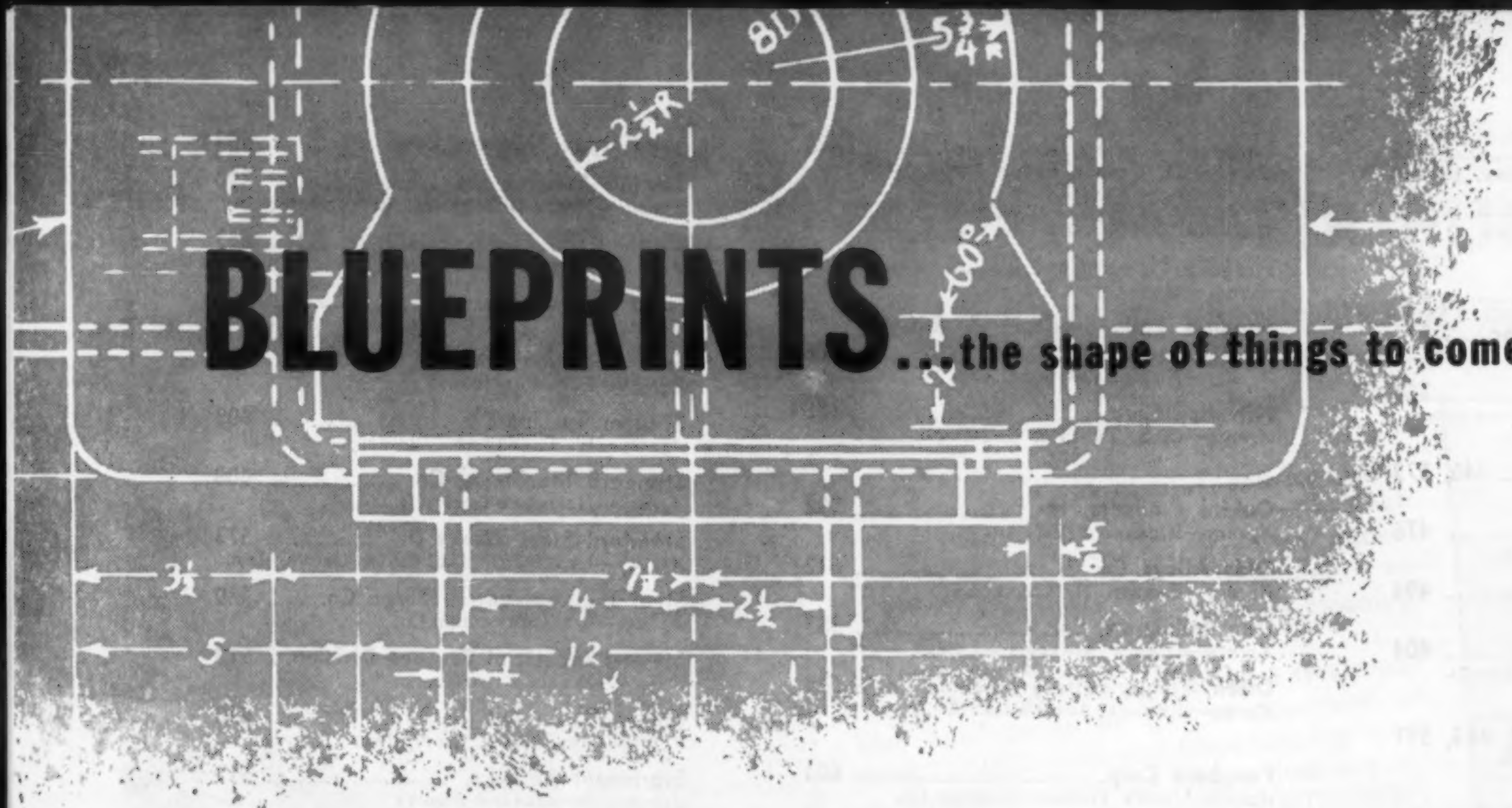
AMERICAN SOCIETY OF TOOL ENGINEERS, annual meeting and exposition. Cleveland, Ohio. April 8-12, 1946.

ELECTROCHEMICAL SOCIETY, spring meeting. Birmingham, Ala. April 10-13, 1946.

NATIONAL PLASTICS EXPOSITION. New York, N. Y. April 22-27, 1946.

OPEN HEARTH STEEL AND BLAST FURNACE & RAW MATERIALS CONFERENCE, annual meeting. Chicago, Ill. April 25-26, 1946.

AMERICAN CERAMIC SOCIETY, annual meeting. Buffalo, N. Y. April 28-May 1, 1946.



BLUEPRINTS...the shape of things to come

Aluminum-Faced Plywood

This is an era of marriage of materials, what with alloying, cladding and plating. Often two or more materials do the job better than one, or more cheaply or lightly. New materials with promise are aluminum-faced plywood or fiberboard—the plywood for trucks and freight cars, and the fiberboard for packaging. The materials are being developed by the foil division of an aluminum company.

Zircon in Enamels and Glazes

Though zircon stands at the bottom of the alphabet, in contrast with aluminum, it is by no means last in its pace of development. In our January issue we mentioned it as an up and coming refractory. Watch its increasing use in enamels and glazes, for it contributes brilliance, hardness, craze resistance and improved mechanical properties. It is found admirable in special porcelains in the field of high physical and dielectric strength insulators and low loss bodies in high frequency electronic applications. Its good future is due in large measure to discovery of new deposits in Australia, India, Brazil and the United States.

Copper-Coated Aluminum

Experimental test runs are being conducted with copper-coated aluminum to compete with brass for electric light sockets and other electrical wiring devices. It is copper, flash coated upon an aluminum sheet to help with soldering. It has a price advantage over brass.

Wire Cords for Truck Tires

Previously in this column we mentioned that in tires for heavy duty trucks steel wire would be used in place of rayon cord. More details are now available. Four plies of medium carbon steel, hard drawn wire will replace 10 plies of rayon cord at one Akron plant. Individual wire filaments will be 0.0058 in. in diam., with three filaments twisted to form a strand and seven strands to form a cable. The wire has 200% greater strength than rayon, and the tire will run 30 deg. cooler because of thinness due to high cord strength and quicker dissipation of heat.

Tin Undercoat Before Painting

Watch for the use of thin tin coating on steel under paint to protect against corrosion, performing the same functions as a phosphate surface treatment. Some experimenters claim that it is easier and cheaper to apply than the "phosphating." The tin coatings tested varied from ½ oz. of tin per sq. ft. up to 2 oz., the latter giving a very superior protection. The tin is applied by electrodeposition. Such treatment may be found in the future on motor car bodies, steel window frames, refrigerators, ranges and steel furniture.

Optical Plastics

Cheapness of home television sets will be partly due to use of plastics for lenses, prisms and mirrors in place of glass, a heritage from plastics optics developed for war purposes. The plastic pieces are ready for use when removed from the glass molds in which they are baked. The laborious optical lens grinding of glass is eliminated. They are suited particularly for large, non-spherical optical parts. Out of 140 organic plastics investigated, two were standardized for war production, one with characteristics of crown glass; the other, of flint glass. The chief "bug" to be exterminated is the tendency to scratch.

Copper in Cast Irons and Steels

One can look for greatly increased use of copper-bearing cast irons and steels shortly. There is no sense in using a man to do a boy's job, and the cheap copper-bearing steels are often sufficient for the job at hand. The use of this material increased from 2,000 tons in 1931 to 13,000 tons in 1941, and during the war it had a great impetus in manufacture of war goods. The metallurgist must be careful not to put too much copper in the steel for mere corrosion resistance. Addition of 0.15 to 0.20% copper cuts corrosion of plain carbon sheet steel exposed to atmosphere by 50%. Higher amounts of copper contribute to strength. Resistance of 18:8 stainless steel to boiling dilute sulphuric acid is increased 90% with 2% copper added. The use of copper, molybdenum and chromium in gray cast iron develops tensile strength of over 60,000 p.s.i.

New Material Tough, Not Rigid

The Army smart boys knew that it was less dangerous to be near a bullet entering sand than one hitting a rock. Sand stops a bullet pronto! For sand, when impacted, conveys from grain to grain and distributes the burden over the equivalent of wide areas. So, for body armor plate they devised a material that was especially tough, without being rigid. It was made of woven glass cloth bonded by plastic resin. The glass cloth bonded plastic is laminated by impregnating a roll of fabric with resin, then compressing a given number of these sheets under heat and pressure. Here comes a parade of peace time applications—light rowboats, containers for gasoline, hydraulic fluids, de-icer fluids, etc.

Low Frequency Induction Furnaces for Steel

The Ajax-Wyatt low frequency induction furnace so widely used for the melting of brass, bronze and other copper alloys and the Ajax-Tama low frequency melting furnace for aluminum may soon have another low-frequency brother especially designed and built for the melting of steels and other ferrous materials. Such furnaces may considerably exceed in power ratings the familiar 375 kw. of the conventional non-ferrous induction melting furnaces and power ratings greater than 600 kw. for some of the larger units being planned.

Adhesive for Rubber

Rubber may be made to adhere to metal and glass more efficiently. Between the synthetic rubber coating and the metal or glass are four layers of cement, the lower two of which contain finely divided metal, or metallic oxide or carbonate particles. A large rubber company has the manufacturing rights.